# LANDSAT INFORMATION FOR STATE PLANNING

## FINAL TECHNICAL REPORT


by

N. L. Faust
ENGINEERING EXPERIMENT STATION

and

G. W. Spann
METRICS, INC.


June, 1977


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George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812


Under Contract Number NAS8-30653
(Project A-1621)



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## Abstract

### LANDSAT DATA FOR STATE PLANNING

The purpose of this project is to transfer remote sensing technology for the digital processing of Landsat data to state and local agencies in Georgia and other southeastern states. The project consists of a series of workshops, seminars, and demonstration efforts, and transfer of NASA-developed hardware concepts and computer software to state agencies.

NASA/MSFC has long had a program of remote sensing assistance to state and local agencies in the southeast. Recently this program has been expanded to include a significant emphasis on the transfer of technology for digital processing of Landsat data. Georgia Tech Engineering Experiment Station (EES) and METRICS, INC. executed a series of tasks demonstrating the usefulness of digital processing technology.

The project includes demonstration efforts utilizing test sites in Douglas County and Hall County, Georgia. These efforts were coordinated by several state agencies including the Georgia Department of Natural Resources, the Georgia Office of Planning and Budget, and the Georgia Department of Transportation. Other tasks accomplished during the project include: calculating the cost-effectiveness of digitally processed Landsat data, holding a series of technology transfer seminars for personnel in several southeastern states, and transferring NASA-developed hardware and software to state agencies in Georgia.

Throughout the multi-year effort, digital processing techniques have been emphasized. The demonstration projects include use of supervised and unsupervised classification algorithms. Software for Landsat data rectification and processing have been developed and/or transferred. A hardware system is available at EES to allow user interactive processing of Landsat data. Seminars and workshops emphasize the digital approach to Landsat data utilization and the system improvements scheduled for Landsats C and D.

Results of the project indicate a substantially increased awareness of the utility of digital Landsat processing techniques among the agencies contacted throughout the southeast. In Georgia, several agencies have jointly funded a program to map the entire state using digitally processed Landsat data.

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# I

# INTRODUCTION

The Georgia Institute of Technology Engineering Experiment Station (EES) has been deeply involved in the formulation, planning, and implementation of a Georgia Natural Resources Inventory since its conception in 1972. During 1972 and 1973 EES presented various State of Georgia agencies with the background information needed to make an initial assessment of the usefulness of digital Landsat information. A trial project was initiated between the Georgia Department of Natural Resources (DNR) and EES in 1973 to test the capability for using digitally processed Landsat data to determine land <u>use</u> in the Atlanta area.[1] At this time several limiting factors in the usefulness of the existing software and the Landsat sensors were discovered. The major problem encountered was that Landsat digital data allowed the mapping of land cover but not land use. This problem is currently attacked by using land cover to infer land use in rural areas, and by using manually collected land use information within cities.

EES has been funded since 1973 by NASA Marshall Space Flight Center (MSFC) to assist the State of Georgia in utilizing Landsat digital analysis for various resource problems within the state. In this multi-year effort several related tasks have been performed in conjunction with numerous state and local agencies within Georgia. The major tasks accomplished during this project are:

- Study of the USGS/NASA land use classification system to determine its applicability to computer processing of Landsat data for suburban land <u>use</u> classification,
- Analysis of state agency user requirements for Landsat data,
- Evaluation of digitally processed Landsat data as an input to the Georgia Department of Transportation planning model,
- Calculations of the cost effectiveness of digitally processed Landsat data as compared to other data sources in conjunction with the Georgia DOT modelling effort.
- Study of botanical indicators of geologic structure,

- Transfer of NASA-developed remote sensing technology (hardware concepts and computer software) to state agencies in Georgia,
- Remote Sensing technology transfer in several southeastern states, and
- A preliminary assessment of the use of Landsat data for identifying under-utilized land on which energy-rich crops could be grown.

The first two tasks were accomplished by digitally processing Landsat data for a portion of suburban Douglas County in an attempt to achieve the highest <u>land use</u> classification accuracy possible utilizing the USGS/NASA land use classification system. This study in cooperation with the Georgia Department of Natural Resources, the Douglas County Planning Department, and the Georgia Office of Planning and Budget (OPB) resulted in 70-80% accuracy figures when compared to aerial photo interpretation.[2] An unexpected result of this project was the recognition that a major, identifiable forest category (loblolly pine) corresponded directly to the trace of the Brevard Fault near Atlanta.

As a continuation of the MSFC-sponsored project, EES determined the land cover for Hall County, Georgia using digital Landsat data. This study was coordinated with the Georgia Department of Transportation (DOT). DOT wished to investigate the feasibility of the use of Landsat land cover information in the Georgia Planning and Land Use Model which was under development at that time.[3] The study of loblolly pine as an indicator of geologic structure was continued during this phase of the project.

The latest phase of this project is designed to assist further the State of Georgia in the application of Landsat digital data to state problems, and the transfer of remote sensing technology to other southeastern states. Software for the classification, geo-referencing, and data base management of Landsat data is being implemented at the Georgia Institute of Technology for use by the State of Georgia. EES has designed and implemented an Earth Resources Digital Analysis system (ERDAS) specifically intended for the processing of remote sensing data. ERDAS is being made available to state, local, and regional users for specific applications.

METRICS, INC. has been involved in this effort since 1975 and is responsible for several tasks under this project. METRICS conducts technology

transfer sessions with agencies from several southeastern states in which the basics of remote sensing and its applications to regional problems are discussed. Additionally, METRICS is responsible for investigating the relationships between land use, energy resources, and remote sensing.

Report Organization

Section II of this report summarizes the early efforts under this project including the study of the USGS/NASA land use classification system, the Georgia DOT Planning Land Use Model study, cost-effectiveness calculations of Landsat data use and analysis of botanical indications of geologic structure. Sections III-VII relate to the latest phase of this project. Section III discusses the evaluation and selection of NASA technology (hardware and software) for transfer to the State of Georgia. Section IV details the activities involved in transferring the classification algorithms and rectification software. Section V describes the development of the Georgia natural resources data base.

Section VI reports on the technology transfer activities which have been a common thread throughout this project but which were emphasized most heavily in this latest phase. Section VII presents a preliminary assessment of the use of Landsat data for identifying under-utilized land for growing energy rich crops. Section VIII gives overall results and conclusions of the effort.

Appendix A gives the details of the Earth Resources Data Analysis System (ERDAS) as implemented at EES.

# II

# BACKGROUND

## Douglas County Test Site

The first test site for the digital classification of Landsat data under this project was Douglas County, Georgia. Douglas County is at an earlier stage in its development than many counties in the Metro Atlanta area. However, several recent and pending events promise to accelerate the growth of this area. Of necessity this means that land use patterns are changing rapidly and will continue to do so in the future. It is important, therefore, in this county that there be planning for the impacts on land use which will occur. For these reasons, Georgia DNR selected Douglas County as an appropriate test site.

The single major cause of the county's present rapid growth in residential and other areas is the recent completion of Interstate 20 into the county. This provides relatively easy access to the area from the center of Atlanta. As usually happens with the opening of a new transportation corridor, many families have chosen to locate along I-20 in Douglas County. Since I-20 presently ends within the county, many people who might otherwise live further from the center of Atlanta, probably locate in Douglas County. For whatever reasons, the recent completion of I-20 into the county seems to have accelerated the growth of the county.

The present rapid growth and the potential for continued expansion in Douglas County is clearly evident. For the Georgia Department of Natural Resources, then, the results of this study provided a base of information on the land use in Douglas County for 1972. It enables DNR to monitor progress and update this base as appropriate.

Land use maps were prepared for that portion of Douglas County which includes Douglasville and the majority of the developed area in the county. The Landsat scene processed was that of October 15, 1972. NASA high altitude photography, also taken in October 1972, was obtained from the EROS Data Center for use in the accuracy evaluations. Supplemental data in the form of field surveys and low altitude oblique photography were also used.

A "quick look" accuracy evaluation was made to ensure that the land use categories identified from Landsat were largely correct. This was accomplished by enlarging the high altitude photography to the scale of the Landsat printout - 1:24,000. A visual comparison of the two products then determined that the results were generally correct with the exceptions noted later in this section.

A pixel-by-pixel accuracy evaluation was completed for a portion of the area. This was accomplished in the following manner: a clear overlay of the 1:24,000 enlargement was prepared as a land use map of the area. Land use was classified according to Level II of the USGS/NASA land use classification system. Approximately 1620 hectares (4000 acres) were compared with Landsat data to provide quantitative accuracy results for each land use category. These results are based on supervised classification techniques using maximum likelihood decision criteria.

It is possible to produce land use maps with a high degree of accuracy using the categories of Level I of the USGS/NASA classification scheme and automatic processing techniques. The categories which can be found and mapped in this test area include: urban or built-up, agricultural land, range land, forest land, water, and barren land. The accuracy of a Level I classification approaches 100%.

The Level II categories which can be identified and mapped include: residential, commercial and services, industrial, extractive, strip and clustered settlement, and open and other; cropland and pasture; deciduous, evergreen, and mixed; streams and waterways, lakes, and reservoir; and bare exposed rock. The categories of Level II present more problems in terms of their unique identification than do the categories in Level I. This is related, in general, to the fact that Landsat measures <u>land cover</u> and the object of the project was to map <u>land use</u>.

## <u>Accuracy Evaluation</u>

Results of the accuracy evaluation of the computer generated land use map are given in Table 1. For the purposes of this evaluation about 10% of the total area was checked for accuracy. This included about 1620 hectares (4000 acres) centered on Douglasville - probably the least accurate area from a classification standpoint.

The photointerpretation was assumed to be correct. Both NASA high altitude photographs and low altitude observations and field checks were used in arriving at the "correct" classifications.

The overall accuracy of the computer-generated map was 67% as shown in Table 1. Accuracies ranged from 87% in the residential category to only 26% for the open category. This low figure results, in part, from an inadequate sample containing open areas and the diverse definition given to open areas.

An area of substantial misclassification was in the three forest categories - deciduous, evergreen, and mixed. Had there been only one category into which all forest areas were classified, the overall accuracy would have risen to 79%. Land use maps generated by and for planning agencies typically have only one category for forest, and this may be a transparent color overlaying all other categories.

While this accuracy is certainly not as high as is desired for most land use maps, the results compare favorably with published results of manual photointerpretation of high altitude photography. In a recent report by Paul L. Vegas[4] at NASA/NSTL, an overall accuracy of 84% was obtained using manual interpretation of NASA high altitude photography. The categories used in the classification were somewhat different from those for Level II categories. However, there is enough similarity to warrant comparison.

Most of the area (approximately 95%) of Georgia is rural. Since the accuracy of this technique is highest in rural areas, it is estimated that 95% of the area of Georgia could be mapped with accuracies in the 80% to 90% range.

| | Res. | Com. | Ind. | Extr. | Trans. | Open | Crops | Decid. | Ever. | Mixed | Water | % Accuracy |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Residential | 1056 | 29 | 5 | 0 | 36 | 2 | 39 | 7 | 30 | 11 | 0 | 87 |
| Commercial | 67 | 178 | 36 | 2 | 11 | 6 | 6 | | 2 | | | 58 |
| Industrial | | | | | | | | | | | | - |
| Extractive | | 7 | 3 | 16 | | | | | | | | 62 |
| Transportation | 56 | 2 | | | 43 | | | | | | | 43 |
| Open | 17 | | | | 3 | 7 | | | | | | 26 |
| Crops | 50 | | | | | | 105 | 2 | 42 | 3 | | 52 |
| Deciduous | 70 | | | | 2 | 1 | | 298 | 34 | 145 | | 54 |
| Evergreen | 45 | | | | 1 | | | 7 | 190 | 53 | | 64 |
| Mixed | 126 | 1 | | | | | | 57 | 88 | 401 | | 60 |
| Water | 1 | | | | 1 | | 1 | 1 | | | 14 | 78 |
| TOTAL | | | | | | | | | | | | 67 |
| TOTAL (with only 1 forest category) | | | | | | | | | | | | 79 |

Correct classifications are indicated along the diagonal, e.g., 1056 pixels were correctly classified as residential but 29 pixels which should have been classified residential were classified as commercial.

TABLE 1. Accuracy of Computer Generated Land-Use Map from Landsat Data. (Numbers in Matrix Indicate Number of Landsat Pixels.)

## Problems Relative to Landsat Processing Using USGS/NASA Land Use Classification System

Some categories of land use are not obtainable from any remote sensor, Landsat or high or low altitude photography. Consider the categories of transportation, communications and utilities. From Landsat or from photography, an airport will not look similar to a rail switching yard, a communications complex, or a utility. A human interpreter can possibly make allowances because of *a priori* knowledge and classify all of the above into a single category. However, it is not possible for even a human interpreter to exactly define the boundaries of the above unless they are fenced in at the boundary or there is a change of vegetation at the boundary.

Many other categories share this problem. It can be difficult to discern the boundary of a park, for example, from either photographs or Landsat computer maps. Clearly supplemental information is required to make a land use map which accurately reflects parameters necessary for intelligent planning.

Part of the problem with an airport, for example, is that there are several types of land cover within the boundary. At the Hartsfield International Airport in Atlanta, there are these categories of land cover: bare ground, concrete, asphalt, large buildings, trees, and grass. On a computer classification map these areas are likely to classify with industrial, commercial, forest, and open and other.

The preceding paragraph outlines a problem which is much more general than just defining the boundaries of a particular category such as transportation/airport. This is the problem of observing land cover and classifying land use. It is apparent in several categories of land use. Residential areas, for example, range from apartment complexes to cluster/condominum homes to single family detached residences with lot sizes from .1 hectare (1/4 acre) to 4-6 hectares (10 - 15 acres) - even in urban areas. It appears that planners generally would like for all of these to be categorized as residential or possibly multi-family/single family residential.

This has proved impossible so far. Contextual information (or _a priori_ knowledge) however, often allows one to differentiate between industrial areas and multifamily residences. With very low density residential areas, particularly those which are heavily wooded, there are likely to be several categories on a computer generated Landsat map. The areas occupied by the houses/lawns/driveways will probably be classified in a category which includes higher density single family residential. The forested areas in between houses, however, are likely to classify as deciduous, evergreen, or mixed. Since these areas are neither open/other nor forests in the true sense of the word, they should be classified residential. This has proved difficult, because to classify these areas accurately would require a decision algorithm incorporating spatial/contextual information.

Another problem arises in a test area such as this which includes both urban and rural land use. Open areas in an urban setting are usually golf courses, parks or other grassy areas. The signature for this category of land use is virtually identical to the signature for pastures - a rural land use. While each of these categories can be identified in its proper setting, there are no unique signatures which apply to these categories separately. One conclusion that may be drawn from this experience is that auxilliary information is needed when converting from land cover to land use.

## Extensions of Computer Processing Efforts

The next phase of the project was designed to extend capabilities for computer land use/land cover classification that were demonstrated in the Douglasville area, and to interact with state and local agencies not previously involved with this project. The ability to classify the data, however, is only the beginning of its usefulness. Once land cover information is available, the usefulness of many planning data bases and models is enhanced. One such model is the transportation planning land use simulation model presently being developed by the Georgia Department of Transportation (DOT). A secondary effort in this phase was a continuation of the search for geobotanical indicators (identified in the Douglas County area) relating to the Brevard Shear Zone.

The Georgia Transportation Land Use Model is currently being developed by the College of Business Administration, Research and Services, University of Georgia, Athens, Georgia, under sponsorship of the Georgia Department of Transportation.

The Georgia Transportation Planning Land Use Model is designed primarily to forecast changes in employment, housing, population, and land use as a result of growth associated with alternatives to selected transportation routes. The Model itself consists of four submodels: (1) Transportation Submodel, (2) Employment Submodel, (3) Population-Housing Submodel, and (4) Land Supply Submodel.

As part of this effort, Hall County, Georgia was selected as a test site for the application of computer processed Landsat data to Transportation Planning problems. Hall County was one of the seventeen counties that have been studied using the Georgia DOT Tránsportation Planning Land-Use Simulation Model. Hall County is presently extremely rural, but because of its proximity to Atlanta, and the presence of Lake Lanier, it is a rapidly changing area that needs an effective land use policy to allocate its resources.

After the Landsat digital tapes for the North Georgia area including Hall County were obtained, an initial clustering analysis was accomplished on the area around Lake Lanier. The clustering results were output at a scale of 1:24000 so that the data could be compared to topographic maps of the area and some low altitude aerial photographs provided by the Georgia DOT. By overlaying the printouts and the aerial photographs on a light table, specific classes such as water, forests, commercial, etc. were identified. Subsequent field checking of these areas by Ms. Pat Sellers of the U. S. Corps of Engineers allowed verification of the identity of the clusters. Once the clusters had been identified, the spectral signature of each class was computed and stored. A classification was then produced using these signatures for the Hall County area. Each supervised class was assigned a particular symbol on the scaled computer map. These symbols were later manually color-coded to produce a land cover map of Hall County (Fig. 1).

Results of Classification

Twelve land cover classes were used for the supervised classification of Hall County. These classes are described below. The corresponding color on the Hall County land cover map and the number of acres for each class are also given. The total area of Hall County is approximately 270,000 acres.

TABLE 2. LAND COVER IN HALL COUNTY

| Class | Color | Description * | HECTARES | Area (Acres) |
|---|---|---|---|---|
| 1 | Blue | Open water | 5110 | (12,627) |
| 2 | White | Hard woods (deciduous) | 46991 | (116,118) |
| 3 | Gold | Mixed-open + deciduous | 12874 | (31,812) |
| 4 | Yellow-green | Conifers | 9818 | (24,260) |
| 5 | Dark green | Open - I | 5503 | (13,599) |
| 6 | Yellow-brown | Low density residential and secondary roads | 11476 | (28,358) |
| 7 | Yellow | Residential | 5862 | (14,485) |
| 8 | Blue-green | Sediment loaded water | 2729 | (6,743) |
| 9 | Brown | Asphalt - commercial | 3454 | (8,536) |
| 10 | Olive green | Open - II | 2887 | (7,134) |
| 11 | Orange | Commercial (large buildings) | 348 | (860) |
| 12 | Red-brown | High density residential | 2309 | (5,705) |
| | | TOTAL | 109361 | (270,237) |

* These categories do not directly correspond to the USGS/NASA land cover classification scheme. They were designed specifically to provide data needed for the Land Supply Submodel.

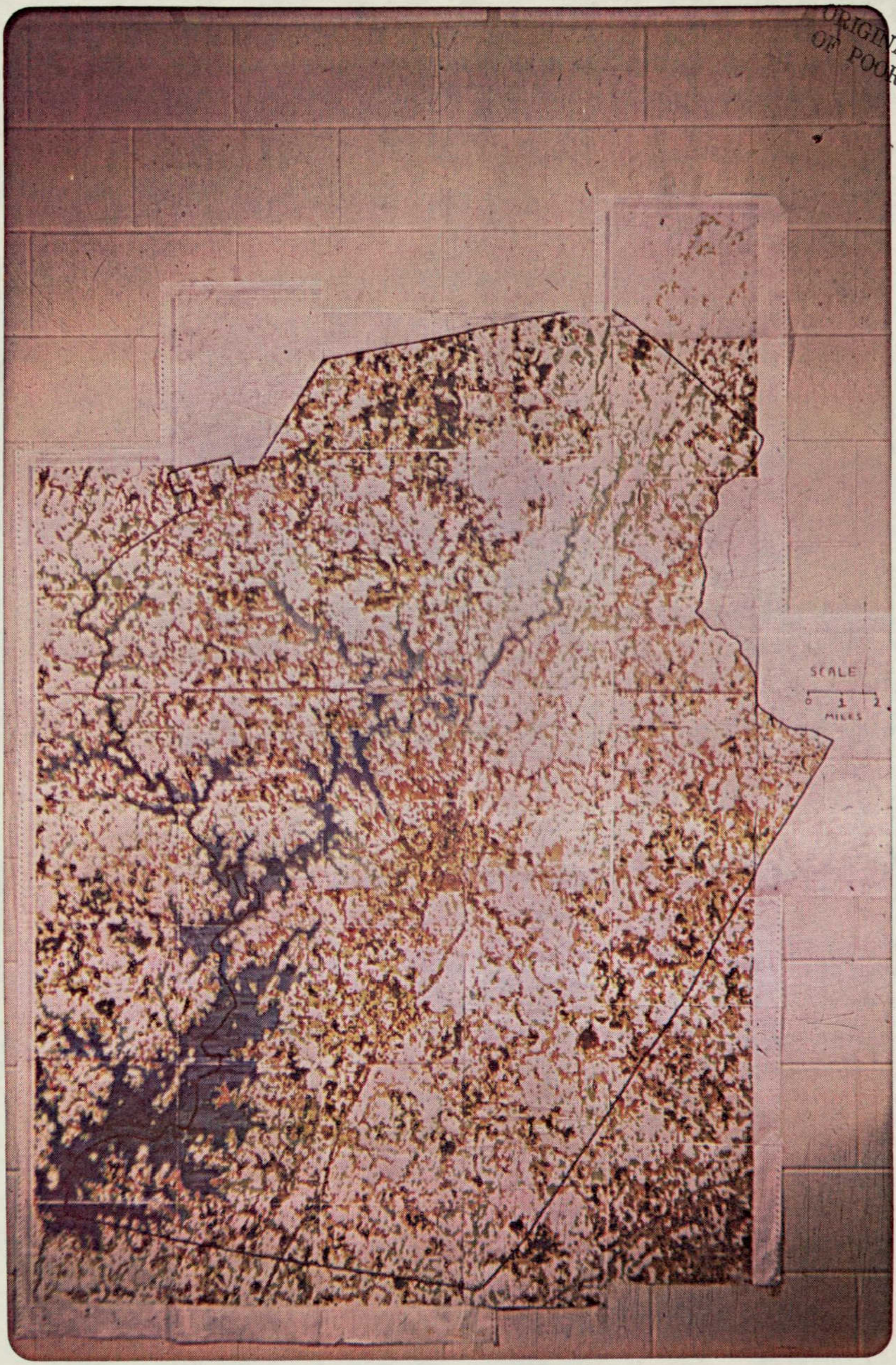


Figure 1. Landsat Classification of Hall County

## Aggregation of Classified Data

The data required for input into the Georgia DOT Land Use Planning Simulation Model are the total county wide acreages of residential, commercial and industrial, water and other. The "other" category is taken to be land suitable for development. No attention is given to the spatial location of the classes within the county since, at present, the model is designed to attack only regional problems. Table 3 below is an aggregation of the above 12 classes into the four required classes.

TABLE 3. LAND USE CLASSES FOR DOT MODEL

| CLASS | | AREA HECTARES | (ACRES) |
|---|---|---|---|
| 1 | Residential | 4098 | (10,127) |
| 2 | Commercial | 759 | (1,875) |
| 3 | Water | 5110 | (12,627) |
| 4 | Other | 99393 | (245,607) |

Several advantages of the digital processing of Landsat Data for this type of modeling effort are:

* Landsat data are available regularly and cover the entire state contemporaneously.

* Landsat data are in gridded form and are well suited for inclusion into a data base.

* Area measurements are available automatically.

* Manual methods of making area measurements are slow and often inaccurate.

* Manual derivation of land use data for the entire state would take an estimated 3.3 man-years; computer processing of the same area could be achieved in six to nine months.

* The computer would have a constant (if any) bias in classifying landcover, whereas, individual interpreters would not.

* Landsat data include locational information for sub-county areas.

Several Disadvantages of Digital Processing of Landsat Data are:

* Photointerpretation and/or field checking may be more accurate than the computer processing technique.

* Existing land use information is often in parcel form, therefore the comparison of Landsat information to existing information is difficult.

* Digital processing of Landsat data gives land cover information, not land use. Auxiliary information must be used to infer land use.

* The definition of some categories in conventional land-use surveys differs from that obtained via Landsat classification or photographic interpretation, i.e. strip mining, chicken raising and farming are all in the same category in a conventional survey.

* The Landsat minimum mapping unit is one acre; therefore it is best suited for regional studies.

## Cost-Effectiveness Calculations

Cost effectiveness calculations were made for the automatic classification techniques used to provide data for the Georgia DOT model. Determination of an exact cost-effectiveness ratio for automatic *versus* manual methods of generating land use data of the type needed by a transportation planning model is, at best, difficult. The calculation is complicated by numerous factors, including:

1. The tendency to use existing data of unknown accuracy when such data are available.
2. The conflicts between using land use data and land cover data.
3. The "quality" of the model in terms of the sophistication and aggregation of the land use data needed.

Nevertheless, this section presents the results of a cost-effectiveness calculation based on inputs from the Georgia Department of Transportation, the University of Georgia and the Engineering Experiment Station. It applies specifically to the data needed for the Georgia Transportation Planning Land Use Model.

Based on current limited land use data gathering efforts sponsored by Georgia DOT at the University of Georgia, it is possible to derive cost estimates for providing state-wide land use data for the Transportation planning Land Use Model. The best available estimates indicate that an average of five man-days per county are needed to produce land use data manually. If an average salary of $15,000 is assumed along with a 100% overhead rate,* the cost per county becomes $625 or approximately $100,000 for the entire state of Georgia. This figure is approximately $0.66 per square kilometer ($1.70 per square mile).

In a previous survey conducted by the Engineering Experiment Station[5] as part of this project, reported land use mapping costs varied from $0.42 to $57.53 per square kilometer ($1.08 to $149.00 per square mile) with an average cost of $24.17 per square kilometer ($62.61 per square mile). Therefore, the $0.66 figure calculated above should probably be considered a <u>minimum</u> cost for manual land use mapping efforts.

EES costs indicated that land cover mapping could be accomplished on the Georgia Tech UNIVAC 1108 for about $0.40 per square kilometer ($1.00 per square mile). Georgia Tech no longer owns a U-1108, however, but now owns a CDC Cyber-74. Because this machine is faster and because of a change in the computer charge structure, it is now estimated that land cover mapping from Landsat data would cost approximately $0.30 to $0.40 per square kilometer ($0.80 to $1.00 per square mile) depending on the amount of analysis required. This cost estimate includes both computer and manpower costs. A current EES/METRICS project sponsored by MSFC is explaining these cost estimates further.

Extrapolating the maximum figure to the entire State of Georgia indicates a land cover mapping cost of approximately $59,000. This is less than half the cost of a manual effort. Furthermore, this mapping could be done in a matter of weeks or months instead of years.

Other studies have produced data consistent with the above cost estimates. While the figures for cost per square mile are not the same as determined in this project, the other studies resulted in data with the same relative magnitude. For example, Table 4 prepared by ECON, Incorporated[6] under NASA contract NASW-2558. The data are in 1973 dollars. In order to make the data comparable to the cost derived above an inflation factor of 26% was added. Results of this calculation are shown in Table 5.

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* The overhead rate given by Georgia DOT was 70%; this was adjusted to 100% as an estimate of a realistic overhead rate, if a private company had performed the study.

These data, of course, show the collection of land cover information to be much less costly via computer processing of Landsat data than by conventional techniques. While costs for manual and automatic data collection are not the same as those found for this project, they bear the same relationship, i.e., manual methods of data collection are much more expensive than automatic methods.

In another study of the Earth Resources Survey program prepared by Earth Satellite Corporation and Booze-Allen Applied Research Corporation[7], different costs were estimated for manual and automatic data collection; but, again, these costs have the same relationship as the costs derived for this project. Table 6 summarizes the EARTHSAT/Booze-Allen estimates (adjusted for inflation). Their original data were presented in 1974 dollars so an inflation factor of 15% was assumed in preparing the table presented here. Again, using Landsat data to supply land cover information is estimated to be much less costly than using other data sources.

TABLE 4

COST OF LAND COVER INFORMATION 1973 $/SQUARE KILOMETER
(1973 $/SQUARE MILE)

| | Manual | | | | | | Automatic | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Satellite | | Aircraft | | Ground | | Satellite | | Aircraft | | Ground | |
| Level I | .05 | (.14) | .44 | (1.13) | 4.25 | (11.0) | .02 | (.048) | .31 | (.80) | 4.25 | (11.0) |
| Level II | | NC | .62 | (1.60) | 4.83 | (12.5) | .07 | (.194) | .37 | (.97) | 4.83 | (12.5) |
| Level III | | NC | | NC | 5.64 | (14.6) | | NC | .55 | (1.42) | 5.64 | (14.6) |

NC = The sensor is incapable of providing required detail

TABLE 5

COST OF LAND COVER INFORMATION 1976 $/SQUARE KILOMETER
(1976 $/SQUARE MILE)

| | Manual | | | | | | Automatic | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Satellite | | Aircraft | | Ground | | Satellite | | Aircraft | | Ground | |
| Level I | .07 | (.18) | .55 | (1.42) | 5.35 | (13.86) | .02 | (.06) | .39 | (1.01) | 5.25 | (13.86) |
| Level II | | NC | .78 | (2.02) | 6.08 | (15.75) | .09 | (.24) | .47 | (1.22) | 6.08 | (15.75) |
| Level III | | NC | | NC | 7.10 | (18.40) | | NC | .69 | (1.79) | 7.10 | (18.40) |

TABLE 6

UNIT COST ESTIMATES
LAND COVER INFORMATION 1976 $/SQUARE KILOMETER
(1976 $/SQUARE MILE)

| Information Granularity | Unit Cost $/Square Kilometer ($/Square Mile) | | |
|---|---|---|---|
| | Without ERS | With ERS Manual | With ERS Automated |
| I Course | 2.19 (5.68) | .14 (.35) | .35 (.91) |
| II Medium | 2.38 (6.16) | .72 (1.86) | .76 (1.98) |
| III Fine | 6.51 (16.85) | N/A | N/A |

Table 7 summarizes the different cost estimates for producing land cover information at a categorization equivalent to Level II of the USGS/NASA land-use description system. Column 1 presents the "best" estimate for computer processing of Landsat data to obtain the land cover information. Column 2 presents the "best " estimate for collection of the land cover data by other, nonautomated means. These data support the contention that computer processing of Landsat data is a less costly method of obtaining land cover information than more traditional methods, and in general can be accomplished in much less total time.

The only other considerations in this cost-effectiveness calculation of the land cover data and the appropriateness of the categories for the Georgia Transportation Planning Model. These topics are discussed in detail below.

TABLE 7

SUMMARY OF COST ESTIMATES FOR GATHERING LAND COVER INFORMATION

| Source | Automatic Processing of Landsat Data $/SQUARE KM | ($/square mile) | Non Automated Data Collection $/SQUARE KM | ($/square mile) |
|---|---|---|---|---|
| Current Project | .30 - .40 | (.80 - 1.00) | .66 | (1.70) |
| EES Estimates | .40 | (1.00) | 24.17 | (62.61 avg.) |
| ECON[6] | .09 | (.24) | 6.08 | (15.75) |
| EARTHSAT/[7] Booze-Allen | .76 | (1.98) | 2.38 | (6.16) |
| Jayroe[8] | .05 | (.13)# | * | * |
| Joyce[9] | .22 - .50 | (.58 - 1.30) | * | * |

#Computer time only
*No estimate given

Results

Since the Georgia Transportation Planning Land Use Model was not planned with Landsat in mind, an exact comparison of the effectiveness of Landsat and conventional data sources is not possible. An example of the problems encountered is the discrepancy in the data classification provided by the normal methods adopted and by the Landsat data. Consider, for example, a 65 hectare (160 acre) farm which might consist of a farm house, several commercial broiler houses and a small country store. Under the methodology currently used in data gathering for the model, all 65 hectares (160 acres) would be classified rural agricultural. In fact no commercial activity outside corporate limits is recognized.

Using Landsat data, however, there would be at least three classifications for this particular geographical area: commercial, residential, and cropland/pasture. While there is little question that Landsat data could serve the needs of the model for land use data, some conceptual revisions would be needed. This possibility is currently being explored.

Results of this study, however, do indicate that digitally processed Landsat data can be a valuable source of land-use data for input to the DOT Model if:

- the data are used along with appropriate supplemental information, and
- several conceptual problems with the model are solved

additionally, the use of Landsat data was found to be a cost-effective method for obtaining the needed land use/land cover data for Hall County for input to the model.

Geobotanical Indicators

In processing the Landsat data for Douglas County a correlation was found in the Douglasville area between one of the tree categories classified from digital Landsat data and a particular soil type derived from a mica schist. This mica schist was found to be an extremely metamorphosed rock unit associated with the Brevard Fault zone in Georgia. Thus, an indirect delineation of a fault zone was accomplished by the classification of Landsat digital data. This unexpected result led to an effort in this phase of the project to determine if a similar type of situation occurred in Hall County. Figure 2, a geologic map of northeast Georgia, shows the Brevard Fault zone extending from the Douglasville area northeast into Hall County. The Brevard Fault zone is a major fault zone and cuts many different rock units. Since the individual rock units metamorphosed along the Brevard Fault are not necessarily of the same composition as those in Douglas County, the identical soil units as found in Douglas County would not necessarily be found all along the fault; however, it was expected that a similar elongated trend in vegetation types in Hall County would be found, and that this trend could also be traced to a rock unit associated with the fault zone.

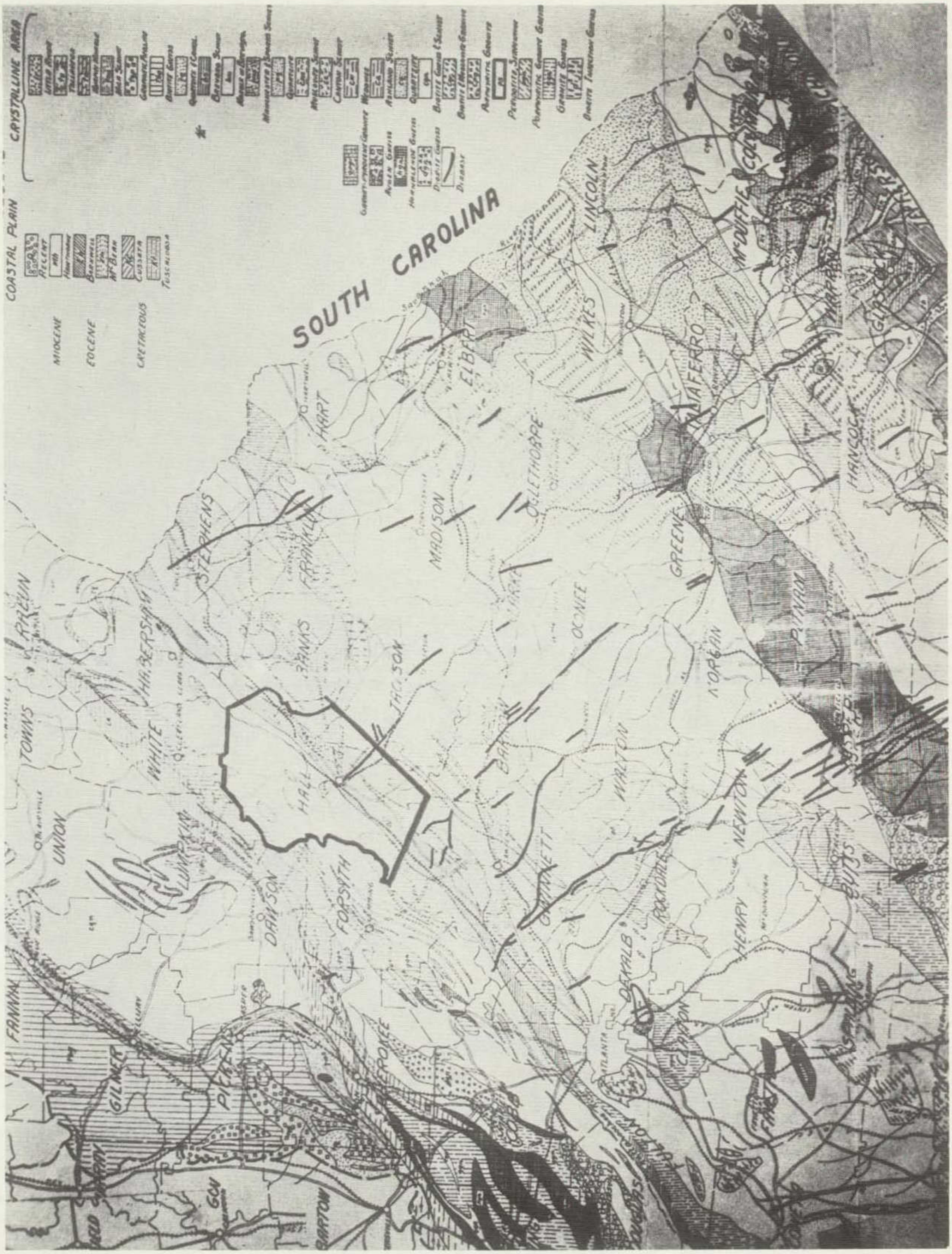
SOUTH CAROLINA
COASTAL PLAIN
CRYSTALLINE AREA
MIOCENE
EOCENE
CRETACEOUS
STEPHENS
FRANKLIN
HART
ELBERT
MADISON
OGLETHORPE
LINCOLN
WILKES
TALIAFERRO
GREENE
OCONEE
MORGAN
WALTON
NEWTON
PUTNAM
HANCOCK
BUTTS
HENRY
ROCKDALE
DEKALB
GWINNETT
JACKSON
BANKS
HALL
HABERSHAM
WHITE
TOWNS
UNION
LUMPKIN
DAWSON
FORSYTH
FANNIN
GILMER
PICKENS
CHEROKEE
BARTOW
FULTON
CLAYTON
DOUGLAS
McDUFFIE

Figure 2.

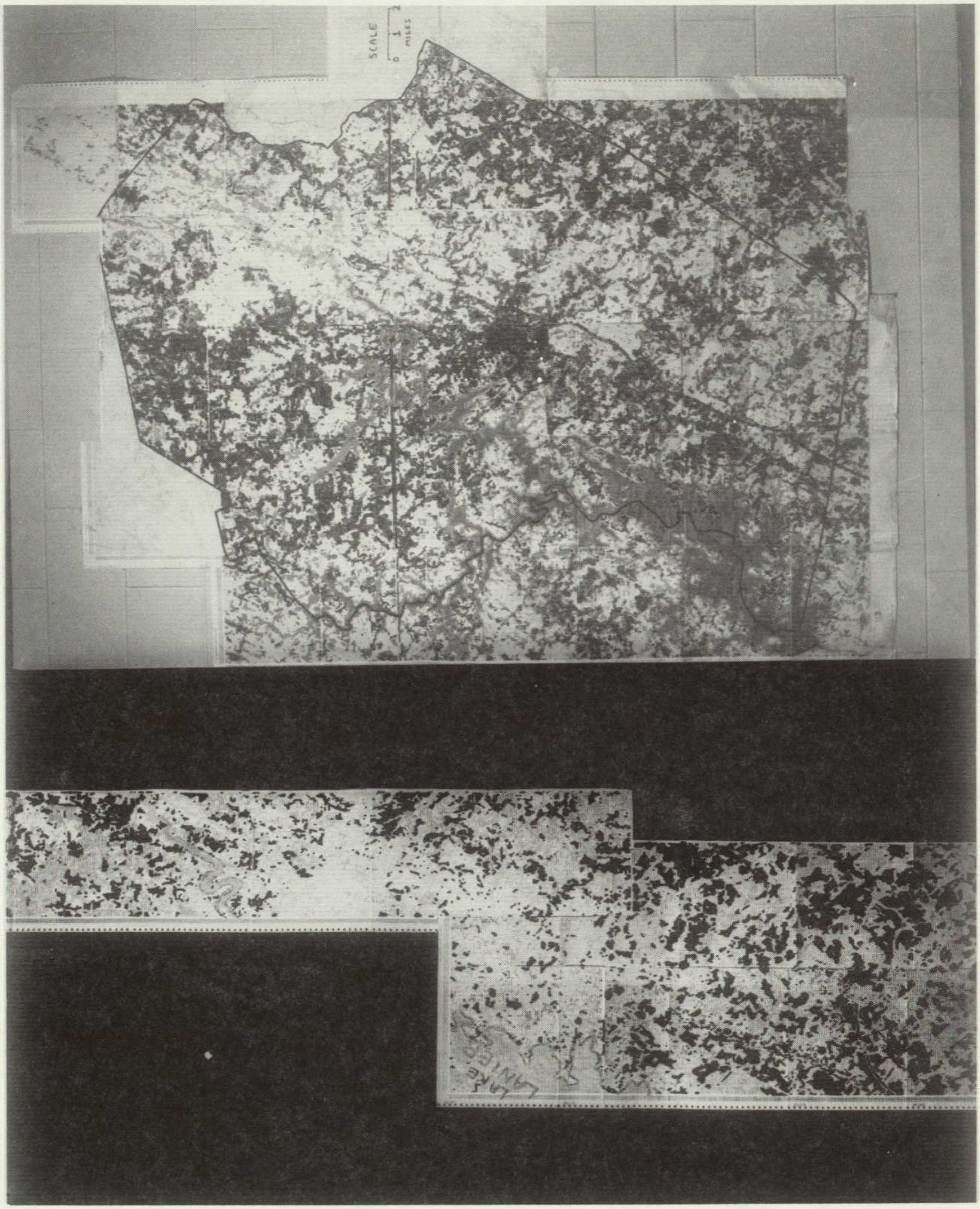

Figure 3.

Landsat data from two seasons were studied in an attempt to detect consistent elongated vegetative trends. Figure 3 shows a clustered April Landsat scene next to a black and white print of the classified data, and Figure 1 shows the October classified data for the whole of Hall County. First, it should be noted that the lake itself trends parallel to the fault zone. Possible fractures parallel to the fault and cross-fractures perpendicular to the fault are indicated by sharp, linear lake inlets.

Figure 1 shows a definite elongated vegetation group (yellow-green) striking northeast. It is most pronounced southeast and northeast of Gainesville. The yellow-green class has been identified with ground truth as loblolly pine. This is the same tree type that was observed to exhibit an elongated pattern corresponding to the Brevard Fault zone in the Douglasville, Georgia area. By overlaying a geologic map on the classified data, one can see the correlation of the loblolly pine vegetation group with a geologic unit, the Brevard Schist. Figure 3 shows in black the same vegetation group in the April 1973 scene. Even though the geobotanical indicators are not as pronounced in the Hall County areas as in the Douglasville area, a definite correlation exists between the vegetation and the area geology. This same techniques should be used in other areas for future verification.

With the implementation of the Georgia Tech Earth Resources Digital Analysis System (ERDAS) described in Appendix A, EES has been able to demonstrate more effectively geobotanical relationships that indicate other fault zones in Georgia. Figure 4 is an enhanced Landsat image of the area around Bartlets Ferry Reservior on the Georgia - Alabama state line. Two fault zones, the Goat Rock fault and the Bartlets Ferry fault have been identified in Georgia and the enhanced image shows a region north of the pine mountain topographic trend that has a tone different than the surrounding area. This tonal change could signify the abrupt change in lithology that occurs over the fault zone. The difference in vegetation has not been detected in ground surveys by Arden and Westra[10]. Figure 5 is a color infrared composite image of three Landsat channels over the same general area described above. The use of the composite mode

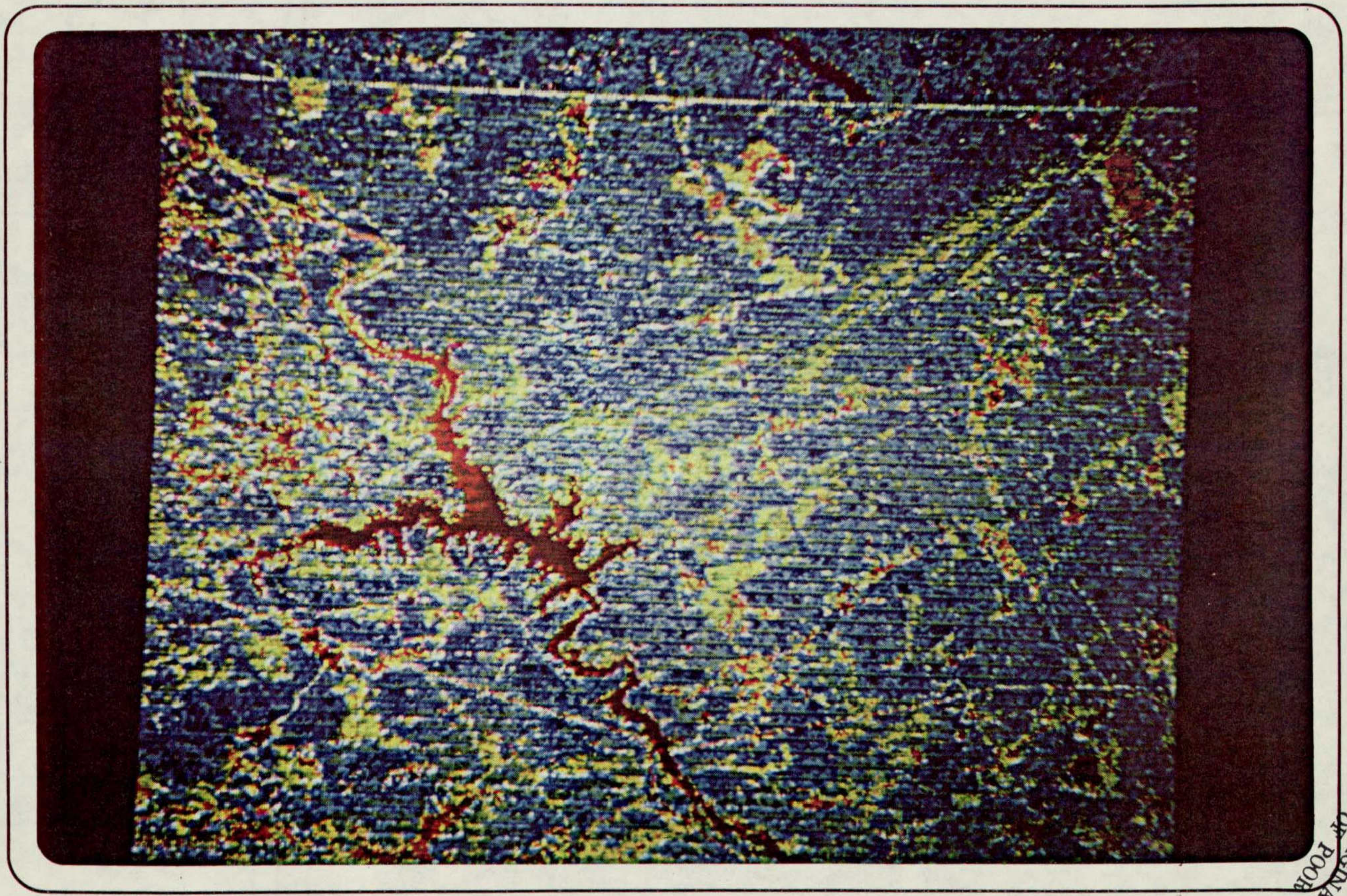

Figure 4. Enhanced Landsat Image

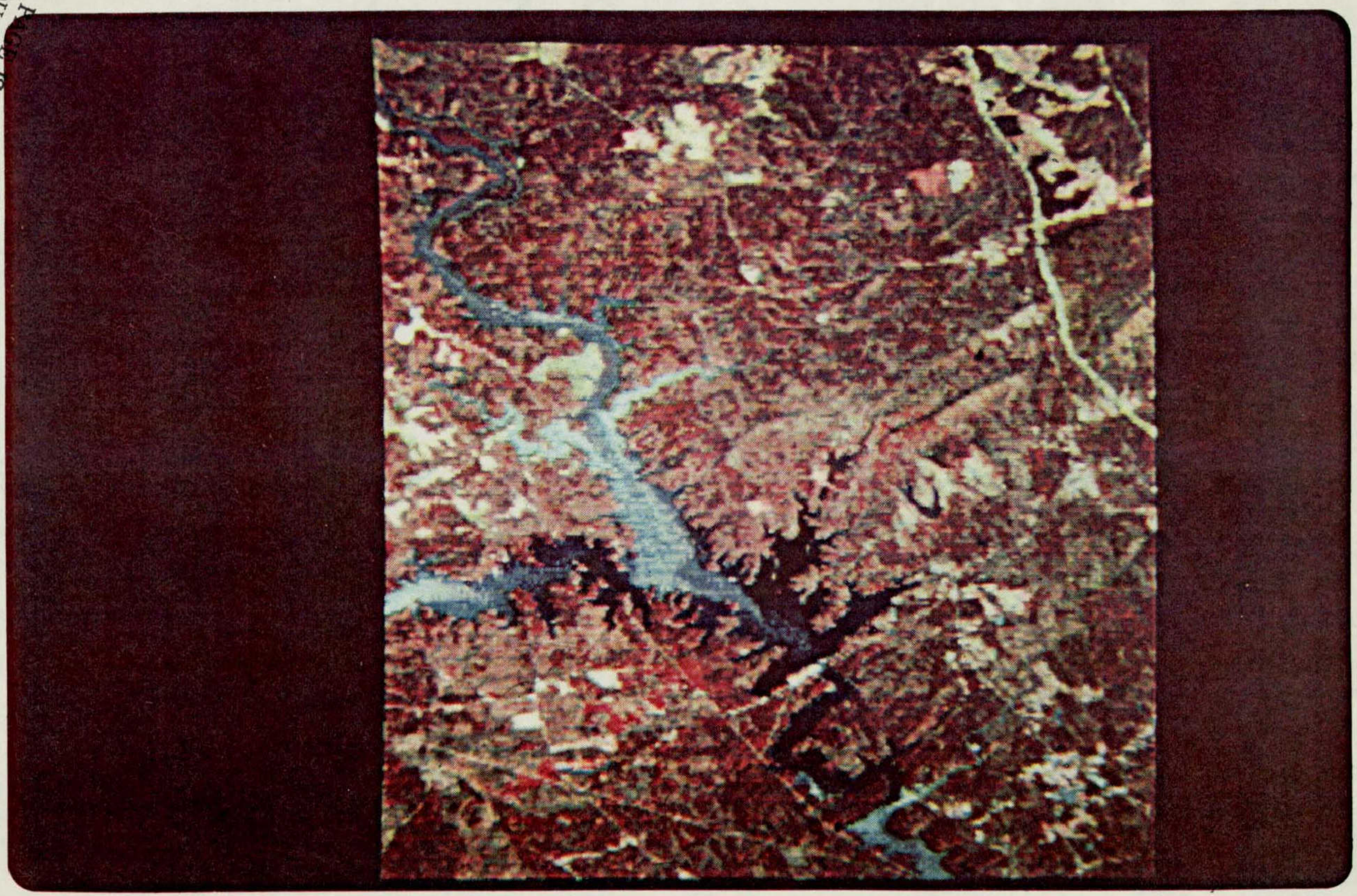

Figure 5. Color Infrared Landsat Image of Bartlets Ferry

of the ERDAS system (Appendix A) gives far more vegetative information than any one channel enhanced alone. Hardwood versus pine differentiation is immediate and many mixed and subcategories may often be identified using this mode. The tonal difference in Figure 5 is represented by a light brown color on the color infrared scene indicating a hardwood land cover.

## III

## LANDSAT SOFTWARE AND HARDWARE FAMILIARIZATION

Before any attempt was made to implement a standard set of Landsat data processing routines on a State of Georgia computer, an extensive effort was initiated to determine state-of-the-art programs available from the various NASA centers. Since travel often was involved in the evaluation of the computer programs, and since there were limited travel funds available, the study was restricted to NASA centers within a reasonable proximity of Atlanta. A parallel effort was also initiated to familiarize EES personnel with the state of the art of digital processing hardware for Landsat applications.

### Software

Before the start of this project, EES had already implemented a basic set of Landsat digital analysis programs obtained from NASA Johnson Space Center (NASA/JSC). This software consisted of the ASTEP (Algorithm Simulation Test and Evaluation Program) and the Purdue LARSYS System. After three years of testing, EES decided to completely devote its efforts to the improvement of the ASTEP System and to eliminate LARSYS because of its inefficiencies. The ASTEP System is designed as a modular program whereby various classification algorithms may be tested against one another using a standard input/output system. ASTEP consists of programs for:

- Maximum likelihood classification
- Feature selection
- Image display
- Clustering
- Mixture processing
- Level slicing
- Input/output

Discussions with personnel from the Georgia Department of Natural Resources indicated that for an operational Landsat processing system to be a reality, software for other classification algorithms and geometric rectification and registration would also have to be implemented in Georgia.

EES investigated software from NASA Marshall Space Flight Center to examine the available software that might be transferred to a State of

Georgia analysis system. Software for the rectification of Landsat data to map co-ordinates using a least squares fit of Landsat data to control points was obtained at MSFC and transfered to a Georgia Tech computer. Other software, such as various spatial clustering algorithms, was studied but has not yet been transferred.

EES and State of Georgia personnel also made several trips to the NASA Earth Resources Laboratory (NASA/ERL) at Slidell, Louisiana. Software for a table lookup formulation for Landsat classification was identified as a desirable element to be included in the Georgia software package. Software for rectification, destripping and polygon location of Landsat data was also transferred. Demonstrations of the ERL software were performed in conjunction with the transfer of technology agreement between the State of Georgia and NASA/ERL.

Hardware

Hardware configurations for the processing of earth resources data were investigated in detail during this phase of the project. EES personnel made trips to NASA/GSFC, NASA/MSFC, NASA/ERL, and NASA/JSC to evaluate various systems in light of the needs of the State of Georgia.

At Goddard, a tour of the facility housing the General Electric Image 100 System was arranged for EES personnel. Literature on the system as well as actual viewing of the operation of the system allowed EES to note the good and bad points of the Image 100 system. Prices of the system were obtained from GE.

During the period of performance of this contract EES was also able to investigate the International Imaging System ($I^2S$) System 101 which is similar to the GE System.

Other systems personally investigated by EES were:

ESL - IDIMS
Bendix - M-DAS

At NASA/ERL much information was accumulated as to the types of equipment needed to support digital processing of Landsat data on an operational basis. Detailed discussions were held with ERL personnel to try to define the cost of a minimal system.

In addition to the site visits to NASA centers and vendor facilities, a large amount of information was gained through brochures from companies making whole systems or those who concentrated on individual pieces of equipment. Since prices and equipment specifications constantly change, EES is attempting to keep up with the technology of digital processing systems for earth resources data. These total systems have been found in this study to range in cost from approximately \$150,000 to \$450,000 depending on the amount of sophistication desired. It was determined, however, that if a user had the technical capability, he could design his own system for a significantly lower cost. The major pieces for a Landsat digital processing system might be:

1) Color display with cursor
2) 16 bit minicomputer with 32,000 or more word storage
3) Disk storage
4) 2 tape drives
5) Printer/plotter
6) Input/output console

## IV

## TRANSFER OF CLASSIFICATION AND RECTIFICATION ALGORITHMS

### Classification Algorithms

Detailed talks were held with State of Georgia personnel to select the classification algorithms to be included in the Georgia digital analysis system software capability. EES discussed existing state-of-the-art classification programs and a joint decision was made as to which programs would be transferred from the various NASA centers. In several cases it was decided that existing EES software would provide the needed capability. The basic algorithms that were included in this category were maximum likelihood, supervised classification, linear supervised classification, and a clustering, unsupervised method. EES has improved these algorithms as implemented on the Georgia Tech Cyber 74 computer.

An improved version of maximum likelihood classification was also developed at EES which uses knowledge about the classification of previous pixels to change the order in which classes are considered. If the computed threshold is less than a specified value only a few classes need be considered. A linear method is initially used in the channel with the most variance to eliminate all but the most probable classes. In addition evaluation of the maximum likelihood quadratic expression

$$(\bar{x} - \bar{u}_i) * V_i^{-1} * (\bar{x} - \bar{u}_i)^T$$

where $\bar{x}$ is the data vector,

$\bar{u}_i$ is the $_i$th class mean vector, and

V is the $_i$th class covariance matrix

may be made more efficient by the expansion of the expression and by using the fact that the class covariance matrix is symmetric. T indicates the transpose of a vector.

The primary classification algorithm that was transferred to the State of Georgia was the ELLTAB table lookup classification algorithm available at the NASA/ERL complex at Slidell, Louisiana. Since this program is extremely complex compared to other classification alrogithms a great deal of time was involved in the conversion attempt. Some of this

time was spent on site at NASA/ERL discussing the program details. The program was initially delivered to EES in a UNIVAC 1108 program format. The difficulty lay in the fact that Georgia Tech was in the midst of a transfer from a UNIVAC 1108 system to a CDC Cyber 74 system. With the help of ERL advice, the program was made to execute on the UNIVAC 1108 before it was removed from the Georgia Tech campus. Experience gained during the short period of time that the UNIVAC was still at Tech was invaluable in learning the concepts used in the ELLTAB program. A parallel attempt was made to convert ELLTAB to the Cyber 74 system. Some problems were encountered, however, the sixty bit word size of the Cyber 74 computer compared to the thirty-six bit size on the UNIVAC made dramatic differences in the way in which the lookup table was constructed and packed. Experience gained on the UNIVAC was invaluable in reformulating the table building method to work on the Cyber 74. Basic file handling procedures were also found to be significantly different on the Cyber from those on the UNIVAC. Word manipulation software common to all UNIVAC systems was found to be lacking in the Cyber software, and replacement software had to be written.

All of these problems were solved by EES and the Office of Computing Services at Georgia Tech. As a result, EES currently has an operational version of ELLTAB on the Cyber 74.

Another computer program essential to the classification process was a destripping program designed by ERL personnel. This algorithm allows the removal of the banding which is present in most Landsat digital data. This banding is the result of a detector malfunction on Landsat and can cause large classification errors if not corrected. This computer program uses a moving average technique on a data set to create an equivalency table which may be used to correct the raw multi-spectral scanner data.

A polygon definition program was also transferred from NASA/ERL. This software is useful in the classification of non-rectangular areas such as counties, census districts, and other political or environmental boundaries. Polygons with up to 100 vertices may be specified by the user.

## Rectification Software

One of the prerequisites to the operational use of Landsat data by state or local agencies is the geographic referencing or rectification of that data to a common map base co-ordinate system such as latitude-longitude or the Universal Transverse Mercator (UTM) system. A parallel procedure used in the comparison of images over the same area for two different time periods is registration. For both types of transformations a system of Ground Control Points (GCP) are located on the Landsat data and on a map or another Landsat image. Easily identifiable features such as road intersections and water/land interfaces are often used as GCP's.

In general, a method is then used which creates a transformation matrix relating to two co-ordinate systems in a least squares sense. This transformation matrix accounts for errors in scale in the vertical and horizontal directions and a rotation angle of the image. Six elements are derived. Four of these make up the transformation matrix and two are scalar additive factors.

The software for the calculation of the transformation matrix using a least squares fit of ground control points was obtained from NASA/MSFC. The computer program, COORD, was adapted to the Cyber 74. It was made operational within a short period of time. Program checkout was completed by comparison of data to sample data sets provided with the computer program. Even though the software may be used to solve nonlinear equations, this application only required the linear least squares solution.

Once the transformation matrix has been derived a method must be used to convert the rows and columns of Landsat data into elements of the new co-ordinate system. This problem is generally known as the resampling problem. To calculate a value for the new element as a function of the old elements, a decision must be made as to the nature of the relation of the two data sets. The simplest method is the nearest neighbor decision rule. By this rule, if a value for a new element is to be determined, the value is taken as that of the nearest old element. This can be visualized as the overlay of two grids, one rotated at an angle of 10 degrees to the other as shown in Figure 6.

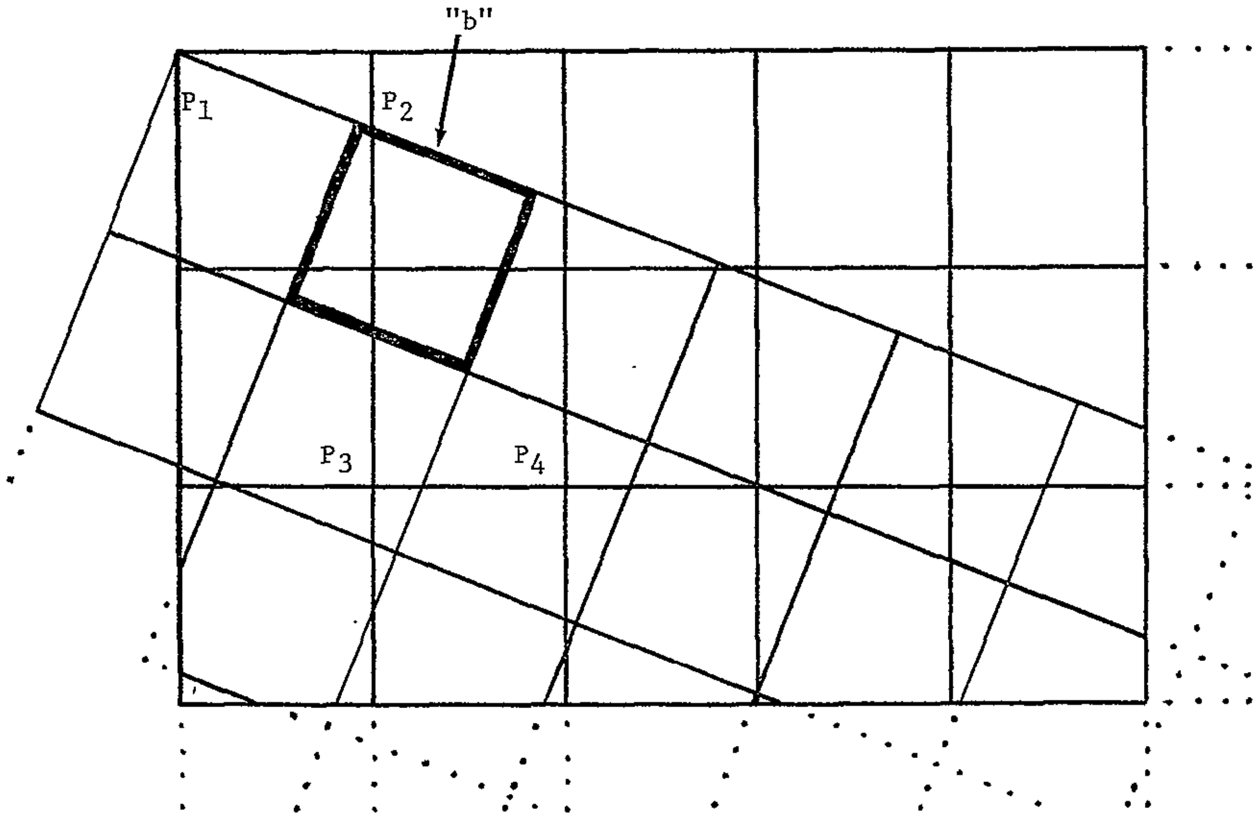


Figure 6. Rectification Configuration

For example, the new sample "b" would be assigned the value of pixel #2 by the nearest neighbor rule.

A second method is the technique of bi-linear interpolation. This method allows the computation of an approximation of the area of each old element covered by a particular new element. For example, the value of "b" would then be determined by an equation of the form

$$"b" = Ap_1+Bp_2+Cp_3+Dp_4$$

where $p_i$ = value of $\text{pixel}_i$. This method is by far the most popular resampling technique in use today.

A third technique, cubic interpolation, requires derivation of a value for the new element from the eight nearest old elements. This method is the most accurate and most time consuming of all methods discussed.

The primary rectification resampling computer program considered for transfer to the State of Georgia was the NASA/ERL program GEOREF. EES received copies of the GEOREF programs which were written for the ERL Varian computer system. ERL software only allowed rectification of previously classified Landsat data and had no provision for the rectification of raw Landsat data. Because of the differences in file structure between the CDC and Varian and because several Varian library subroutines were necessary for the execution of GEOREF, EES decided to design, code, and implement its own version of a resampling program. EES designed the program RECTIFY to accept either raw or classified Landsat data and to use either nearest neighbor or bi-linear interpolation at the user's request. This program was designed primarily for the CDC Cyber 74 but can easily be transferred to other computers. Mass storage as well as central processor storage requirements may be varied to optimize performance on any computer system. RECTIFY is written entirely in Fortran IV for implementation ease. A tradeoff exists between core storage requirements and mass storage input/output time. Where a large amount of central processor storage is available, it should be used to full advantage to decrease execution time.

V

# GEORGIA DATA BASE DEVELOPMENT

## Introduction

The State of Georgia has long had an interest in the development of a common data base from which all state agencies could draw information relating to specific policy and operational decisions in a dynamic manner. As is often the case in state government, decisions are normally made without all available information because the bureaucratic structure does not allow free information exchange between different agencies or the methods for obtaining the data are too slow and cumbersome to provide the data in a timely fashion.

There are, however, many pitfalls on the way to the design of an efficient information retrieval system. Many data base efforts have been decimated by costs associated only with the acquisition of data. An objective view as to the types of data needed statewide, the types and numbers of potential users of the data base, and the policy as to the accessibility of the data must be developed prior to any data collection effort or computer implementation.

The State of Georgia is making a comprehensive attempt at evaluating all the factors affecting the data base concept before embarking on a long term project. A compilation of all state agency data needs was completed by the Georgia Office of Planning and Budget (OPB) during the last year. Direct contacts with state agency personnel provided the information needed to assess what types of data are needed statewide and to define areas in which there is overlap in data collection programs currently underway. Once this step was accomplished, each agency was made aware of the other agency data collection efforts that could be used to supplement its own data, and in some cases where the data were gathered at the same scale, to eliminate or combine existing efforts.

In addition to the data needs study, a parallel effort was launched to investigate the existing state-of-the-art in information systems and data base retrieval systems. An ad hoc committee was formed with EES, DNR, OPB, and the Department of Administrative Services (DOAS) all contributing. Only information systems in the eastern United States were seriously considered since travel money was not abundant. The purpose of this committee was to evaluate potential information systems that might be implemented in the State

of Georgia. EES acted as a technical reviewer of the systems and provided input to the committee as to the transferability of the systems to State of Georgia computers and the analysis potential of each system.

Systems Evaluation

As a first step in the evaluation of specific information systems for possible transfer to the State of Georgia, a trip was arranged to Oak Ridge National Labs (ORNL) and to TVA. Representatives from the Georgia Department of Natural Resources, Georgia Office of Planning and Budget, the University of Georgia, Georgia Tech, and METRICS visited both installations. At ORNL, the Oak Ridge Regional Management and Information System (ORRMIS) was described in detail. Even though the concept of ORRMIS was considered to be good, the practicality of conversion of the system to a State of Georgia computer was questioned because of various machine dependent computer programs that were an integral part of the system.

The next stop on the trip was the Tennessee Valley Authority (TVA) complex at Norris Dam, Tennessee. TVA had recently adapted a version of the Harvard IMGRID program to its computer and had started to incorporate parts of the ORRMIS technology into its system. At the time of our visit TVA was initially testing the IMGRID System with small data bases from the TVA region. The representatives were favorably impressed with this system although it was in the early stages of implementation.

A trip was then made by the members of the committee to Boston to further investigate the IMGRID system. The IMGRID system was developed at Harvard Graduate School of Design in the Department of Landscape Architecture, partially under support of the National Science Foundation (NSF). The committee was invited to a NSF project review at which the IMGRID system and the dynamic models which interact with the data base were described in detail. The obvious applications of a system such as IMGRID and its models to natural resource, economic, and housing problems excited the committee members and provided a basis for their acceptance of IMGRID as a viable data base management tool for the State of Georgia. Probably the greatest selling point of the IMGRID system is its simple interactive control language system which used key words to access software techniques. The language is designed so that managers may themselves interact with a data base and get timely information on which to make policy decisions.

Finally, as a part of the previously mentioned NASA/ERL - State of Georgia transfer of technology agreement, the committee went to Slidell, Louisiana to investigate the data base system at ERL. This system was found to be excellent in its ability to incorporate Landsat data into a data base, but its modeling interface and control language were not considered to be as flexible as those of the Harvard System.

Another factor which influenced the State's decision as to which system to use was the fact that there are three persons in the Office of Planning and Research of DNR who are intimately familiar with the IMGRID system and its operation. All three of these persons recently obtained master of science degrees from the Harvard School of Design, and actively used IMGRID enroute to their degrees.

As a result of the evaluations of existing data base systems, the IMGRID system was designated as the most likely system to be implemented in the State of Georgia because of its ease of use, ease of model integration, and because of the existing experience within DNR in its operation.

Software Coordination

EES also acted as the software co-ordinator for this effort. A deck of cards was obtained from Harvard, and EES made the system operational on the Georgia Tech Cyber 74 computer. Some software conversion was necessary since the IMGRID routines were designed to operate on an IBM computer.

A prototype data base retrieval and modeling project has just been initiated in the Office of Planning and Research of DNR. The personnel already familiar with IMGRID will gather data over a small selected test area near Atlanta and will derive models for the identification of areas most suitable for solid waste management sites as well as other applications. This study is envisioned to take only 2 to 3 months to complete. When this is done, an example project for data specific to Georgia will have been completed and costs for accomplishing similar modeling tasks will be addressed. It is expected that many state agencies will follow OPR's lead and wish to have trial projects for their specific management applications. At this point or earlier, EES will transfer IMGRID to a computer located at the State of Georgia Office Buildings, but will continue development of models and data base retrieval techniques on the Cyber 74.

One problem which has not been completely resolved to date is the definition of the co-ordinate system for which the statewide data base retrieval system will reference data. A UTM zone change occurs in the middle of the State of Georgia and thus makes statewide use of that system relatively inconvenient. However, the alternative, a latitude-longitude system has different distances on the ground for one second of arc. Even though the system is not conceptualized as going statewide immediately, an interim decision has been made, at least for the prototype project, to go with a latitude-longitude system with a conversion available to UTM co-ordinates. This decision is subject to review before a state wide system is implemented. The point is made that other southeastern states are using UTM and that Georgia might want to be compatible with surrounding states; nevertheless it is felt that having the necessary conversion capability available will tend to minimize the problem.

## Earth Resources Data Processing System Selection

EES has long recognized the necessity of the acquisition of special purpose hardware for any long-term program for the digital processing of Landsat and other remotely sensed data. Large scale Landsat digital classification could not be attached in a reasonable manner using only computer printouts for both training field selection and data display. To acquire adequate training samples, calculate statistics, classify data, and rectify the classified images to a standard coordinate system within a finite amount of time for the whole State of Georgia was a virtual impossibility without some sort of interactive video display tied to a powerful digital processing system.

Georgia Tech EES, realizing the desire of State of Georgia Agencies to incorporate digital Landsat data into their planning activities on an operational basis, approved the design and acquisition of the Earth Resources Data Analysis System (ERDAS). This system is presented in more detail in Appendix A. EES was responsible for selecting and integrating both the hardware and software components of the system.

EES conducted a survey of the digital processing hardware on the market, and formulated a concept for the ERDAS system based on:

1) low cost
2) system flexibility
3) system expansion potential
4) compatibility with other EES computer systems and
5) system reliability and in-house support capability

Using a hypothetical, optimal system, various computer, image display, magnetic tape, mass storage, and printout systems were investigated relative to their desirability for ERDAS. The system described in Appendix A was assembled at Georgia Tech for a total hardware cost of approximately $80,000 (prices as of April, 1976). Thus, for a capital expenditure within reach of State and Regional Planning Agencies, a system was constructed that is capable of processing digital remotely sensed data in an efficient and timely manner.

## VI

## ADDITIONAL TECHNOLOGY TRANSFER EFFORTS

### Background

The formal technology transfer sessions undertaken as a portion of this project were the latest in a series of technology transfer efforts by EES for persons in the Southeast. In 1973 formal presentations were made at a series of Atlanta Regional Commission/Georgia Tech Environmental Resources Center seminars held throughout the year. In 1974 a two-day short course on applications of remote sensing was held at Georgia Tech. As part of the early phases of this project, numerous formal and informal sessions were held with the planning and resources agencies in Georgia, particularly in conjunction with the land use mapping effort in Douglas County. An interim technical report[2] containing the results of the Douglas County mapping effort was prepared and distributed to about 150 attendees at the Symposium on the Utilization of Remote Sensing Data in the Southeastern United States, January, 1975 at Athens, Georgia. In addition to the report, a questionnaire concerning user needs for remote sensing data was circulated. Results of the questionnaire evaluation were contained in the Mar., 1975 report[11] on this project.

Additional interactive technology transfer sessions were held with agencies which participated in the evaluation of Landsat data use for state planning with particular emphasis on the Georgia Department of Transportation's (DOT) Planning Land Use Model. Besides Georgia DOT, the Georgia Department of Natural Resources and the Georgia Office of Planning and Budget participated in the study.

The general consensus resulting from the informal technology transfer efforts in the early phases of this project was that the effort should be formalized. The result of this remote sensing decision was a more formal program of remote sensing technology transfer in conjunction with the research activities on the project.

### Introduction

Formal technology transfer efforts on this project consist of three major technology transfer seminars scheduled by METRICS with participants

from several Southeastern states. These seminars were held at:

1. The University of Tennessee, Knoxville, Tennessee, July 16, 1976
2. Georgia Tech, Atlanta, Georgia, January 28, 1977
3. Clemson University, Clemson, South Carolina, March 22, 1977

METRICS also provided a speaker for the remote sensing workshop held at Georgia Southwestern College, Americus, Georgia, on May 14 and 15, 1977. This conference was sponsored by MSFC.

University of Tennessee Seminar

The first technology transfer seminar on this project was held at the University of Tennessee in cooperation with Dr. John Rehder and Mr. Dale Quattrochi of the University of Tennessee, Department of Geography. With the aid of Dr. Rehder, notices of the meeting were widely distributed throughout Tennessee and surrounding states. A copy of the program agenda is shown in Exhibit 1. Participants in the program included 22 people from about a dozen agencies in three states: Alabama, Kentucky, and Tennessee. A list of attendees is shown in Exhibit 2.

A specific objective of this conference was audience interaction with the speakers. Consequently, approximately two hours was set aside for discussion and questions. One indicator of the probable success of the conference in obtaining this goal was the discussion by a large fraction of the audience who remained for the entire period.

During the discussion period several agencies related their experiences with and plans for the use of Landsat data. For example, a representative from TVA described extensive mapping efforts that TVA was undertaking using high altitude aerial photography and Landsat data. Among the items in progress or planned were:

- Land cover mapping of 15 quadrangles at 1:24,000 for a wet lands investigation
- Delineation of watershed characteristics for use in computer modeling of potential flood hazard
- Water quality analyses
- Development of a computer based information system to correlate forests

EXHIBIT 1

Agenda

REMOTE SENSING TECHNOLOGY TRANSFER SESSION
UNIVERSITY OF TENNESSEE
KNOXVILLE, TENNESSEE

July 16, 1976

| | |
|---|---|
| 10:00 | Introduction of Participants and Audience, Dr. John Rehder |
| 10:05 | Purpose of Meeting, Mr. G. William Spann |
| 10:15 | Landsat Follow-on Description, Mr. G. William Spann |
| 10:45 | Design of a Natural Resources Information System to Include Digital Remote Sensing Inputs, Mr. G. W. Spann |
| 11:15 | Remote Sensing Applications, Dr. John Rehder and Mr. Dale Quattrochi |
| 11:45 | Lunch |
| 1:00 | Digital Processing for Land Use Change Detection, Mr. G. William Spann |
| 1:30 | Discussion, Q & A, Dr. John Rehder, Mr. Dale Quattrochi and Mr. G. William Spann |
| 3:30 | Adjourn |

EXHIBIT 2

Attendees

REMOTE SENSING TECHNOLOGY TRANSFER SESSION
UNIVERSITY OF TENNESSEE, KNOXVILLE, TENN.
JULY 16, 1976

Roger Sparry
Chattanooga, TN

Wayne Beard
U. of Tennessee
Dept. of Forestry
Knoxville, TN

Y. M. Honycutt
ORNL
Oak Ridge, TN

E. T. Luther
Tenn. Div. Geol
Nashville, TN

Clenton Smith
Knoxville, TN

Wm. G. Adams
E. Kentucky University
Richmond, KY

Samuel A. Hall
Dept. of Geo.
E. Kentucky University
Richmond, KY

John C. Rermie
Dept. of Forestry
Knoxville, TN

Rick Cannada
TVA Water System Dev.
Norris, TN

Tom Escue
Marshall Space Flight Center
Huntsville, AL

Ed Baker
TVA
Knoxville, TN

Richard Skaggs
TVA
Knoxville, TN

Jim Blackburn
TVA
Knoxville, TN

Este L. Hollyday
USGS
Nashville, TN

Waddell M. Herron
Navigation Dev. & Regional Studies
TVA
Knoxville, TN

Alan W. Voss
TVA-Mapping Services Branch
Chattanooga, TN

C. E. Clark
ETSU
Dept. of Geography
Johnson City, TN

Birney R. Fish
Kentucky Dept. Natural Resources
Frankfort, KY

Jay Tullos
TSPO
Knoxville, TN

Ronald McCann
CARCOG/SETDD
Chattanooga, TN

Ben Bryan
Geologic Services Branch
TVA
Knoxville, TN

EXHIBIT 2 (Continued)

Richard Mashburn
Oak Ridge National Lab
Oak Ridge, TN

Dr. John B. Rehder
Dept. of Geography
University of Tennessee
Knoxville, TN

Dale A. Quattrochi
Dept. of Geography
University of Tennessee
Knoxville, TN

G. William Spann
METRICS, INC.
Atlanta, GA

classified from Landsat with data from a forest inventory

The data source for mapping the 15 quadrangles was 1:130,000 scale high altitude aerial photography. Computer processed Landsat data are used in the last three activities. In the water quality analysis project, rectification and temporal overlay of Landsat data for four different dates is planned.

A representative from the Kentucky Department of Natural Resources also discussed some of the remote sensing activities of his agency. Seven of the ten divisions within the department have interest in or responsibility for inventorying and monitoring the environment. Major remote sensing activities were oriented toward strip mine inventory and strip mine reclamation monitoring. The department is conducting a Landsat 2 study of strip mine surveillance. A significant portion of the effort is concerned with calculating the cost effectiveness of Landsat data utilization as compared to other means.

Several questions precipitated an extended discussion of geographic information systems. Several systems, utilizing both land resource data from remote sensing and socio-economic data, were described by members of the audience familiar with particular systems. Examples of the various systems discussed are:

- OLDMAN System (in use at the Tennessee State Planning Office)
- Triangle System (a polygon system based on triangles used in Kentucky)
- ADAPT System (used in Virginia)
- LUDA System (sponsored by the USGS)

In response to a question concerning the LUDA system, a representative from USGS described the program in detail. He also discussed several other USGS programs associated with LUDA including the Land Information Analysis program and the International Geographical Union study of geographic information systems sponsored by USGS.

Several other questions were raised concerning specific applications of Landsat data. Applications discussed included: use of Landsat data for population estimation, wet lands classification systems for use with remote sensing data, and land resource mapping.

## Georgia Tech Seminar

The second major technology transfer session under this project was held at the Georgia Tech Engineering Experiment Station on January 28, 1977. Mr. N. L. Faust of Georgia Tech and Mr. Lawrie Jordan of the Georgia Department of Natural Resources assisted in the presentation. Notices of the meeting were widely distributed to individuals and organizations in several Southeastern states. A copy of the agenda is shown in Exhibit 3. Attendees at the meeting included thirty people from nineteen government agencies and one private company located in five states: North Carolina, South Carolina, Alabama, Georgia, and Florida. A list of attendees is shown in Exhibit 4.

A primary objective of this session was demonstration of the Georgia Tech Earth Resources Data Analysis System (ERDAS) to officials from other states. ERDAS was designed and implemented with technical assistance provided by MSFC and NSTL but with funds provided by Georgia Tech and the State of Georgia. To demonstrate the system effectively, the audience was divided into two segments and one segment was provided with a one hour laboratory session while the other segment met in the conference room. This technique appears to have facilitated communications among all of the participants.

Because of the need for an extensive demonstration of the ERDAS, a much shorter question and answer period followed the second seminar. Major topics of discussion were: the Landsat D system, the applications of ERDAS to resource inventories, and the Georgia Land Resource Data Base.

## Other Efforts

In addition to the seminars discussed above, two additional presentations concerning the Landsat C and D programs were made. The first was in conjunction with the Georgia-South Carolina Section of the American Society of Photogrammetry. The meeting was held in Clemson, S. C. in March 1977 and was attended by approximately 40 persons. The second was at the MSFC-sponsored remote sensing workshop held at Georgia Southwestern College, Americus, Georgia in May 1977.

At both meetings formal presentations of the Landsat C and D capabilities were followed by question and answer sessions. Generally the questions related to improvements in land use/land cover mapping which could be achieved

EXHIBIT 3

Agenda

REMOTE SENSING TECHNOLOGY TRANSFER SESSION
GEORGIA TECH ENGINEERING EXPERIMENT STATION
ATLANTA, GEORGIA

January 28, 1977

| | |
|---|---|
| 9:30-9:40 | Welcome, Mr. J. W. Dees |
| 9:40-10:00 | Introduction, Mr. G. William Spann |
| 10:00-10:20 | Marshall Space Flight Center Activities, Dr. C.T.N. Paludan |
| 10:20-10:30 | Coffee |
| 10:30-11:15 | Landsat D, Mr. G. William Spann |
| 11:15-11:45 | ERDAS Introduction, Mr. N. L. Faust |
| 11:45-1:15 | Lunch |
| 1:15-2:15* and 2:15-3:15* | Remote Sensing in Land Resource Data Bases, Mr. G. W. Spann and Georgia's Plans for a Land Resource Data Base, Mr. Lawrie Jordan |
| 1:15-2:15** and 2:15-3:15** | ERDAS Demonstration, Mr. N. L. Faust |
| 3:15-3:30 | Questions and Answers, Wrapup, Mr. G. William Spann, Dr. C.T.N. Paludan, and Mr. N. L. Faust |

* In the Conference Room.

** In the Laboratory.

## EXHIBIT 4

### Attendees

REMOTE SENSING TECHNOLOGY TRANSFER SESSION
GIT/EES - ATLANTA, GA - JANUARY 28, 1977

Steven Osvald
U.S. Army Corps of Eng.
Savannah, GA

Ronald Keeler
Coastal Area Planning
& Development Comm.
Brunswick, GA

Robert C. Moore
Ga. Dept. of Transportation
Atlanta, GA

Susan Simms
Ga. Dept. of Transportation
Atlanta, GA

Raiford Morgan
Altamaha Georgia Southern APDC
Baxley, GA

Bill Williams
Altamaha Georgia Southern APDC
Baxley, GA

George Edwards
U. of Fla. IFAS AREC LA
Lake Alfred, FL

Carlos H. Blazquez
U. of Fla. IFAS AREC LA/KSC
NASA/SA-APP,
Kennedy Space Flight Center, FL

U. Reed Barnett
NASA
Kennedy Space Flight Center, FL

Mary Shaw
Ga. Dept. of Transportation
Atlanta, GA

Connie Blackmon
Atlanta Regional Commission
Atlanta, GA

Russ Desmelik
Atlanta Regional Commission
Atlanta, GA

Tom Smith
Atlanta Regional Commission
Atlanta, GA

Rebecca Slack
USDA, Southeast Watershed Research Lab
Russell Research Center
Athens, GA

Bill Padgett
USDA, Forest Service
Atlanta, GA

Bill Clerke
USDA, Forest Service
Atlanta, GA

W. Joe Lanham
Clemson University
Clemson, SC

Bob Barker
St. Regis Paper Co.
Jacksonville, FL

Roger Beatty
St. Regis Paper Co.
Jacksonville, FL

D. W. Kolberg
North Georgia APDC
Dalton, GA

EXHIBIT 4 (Continued)

Jim Haddox
State of North Carolina
Dept. of Natural and Economic Resources
Raleigh, NC

Bill Kroeck
Environmental Planning Div.
Atlanta Regional Commission
Atlanta, GA

Roy Welch
Dept. of Geography
Universityof Georgia
Athens, GA

Masa Aniya
Dept. of Georgraphy
University of Georgia
Athens, GA

Ted Paludan
NASA/Marshall Space Flight Center, AL

Ed Lane
Bureau of Geology
State of Florida
Tallahassee, FL

Jon Beazley
State Topo Engr
Dept. of Transportation
Tallahassee, FL

D. S. Newton
Dept. of Transportation
Tallahassee, FL

John G. Labie
Florida Coastal Zone Planning DNR
Tallahassee, FL

Hewson Lawrence
U.S. Bureau of Mines
Columbia, SC

using the Landsat D data and the applications for the thermal data available from Landsat C.

## Results

Throughout this project technology transfer efforts have been concentrated in Georgia. An examination of the results of these efforts in Georgia is therefore appropriate. Probably the best indicator of the success of the transfer efforts is the number of agencies which have committed funds and/or personnel time to a project to map the entire State of Georgia using Landsat data. This project is concerned with mapping land cover using Landsat data processed with ERDAS and, where appropriate, inferring land use.

The agencies which have committed funds to the mapping project include:

Georgia Department of Natural Resources
- Environmental Protection Division
- Game and Fish Division
- Office of Planning and Research

Georgia Forestry Commission

Georgia Office of Planning and Budget
- Bureau of Community Affairs

U. S. Department of Agriculture
- Soil Conservation Service
- Forest Service

United States Army Corps of Engineers
- Fort Benning
- Savannah Engineer District

North Georgia Area Planning and Development Commission

Coosa Valley Area Planning and Development Commission

Other organizations which are interested but as yet have supplied no funds include:

Georgia Department of Natural Resources
- Earth and Water Division

Georgia Department of Transportation

Five other area planning and development commissions

VII

# ENERGY RELATED RESOURCES EVALUATION

## Introduction

A portion of METRICS' effort under this project was to investigate the relationships between energy resources, land use, and remote sensing. Three subtasks were defined as follows:

* Collection of available and relevant data on the location of Georgia's energy resources for inclusion in a statewide natural resources data base along with remote sensing data;
* Identification and definition of projects wherein remote sensing would serve as a useful tool in investigating the relationships between land use and energy resources/utilization; and
* Investigation of the potential for using Landsat data to assess the availability of under-utilized land in Georgia for growing energy-rich crops.

The first subtask was accomplished via a search of the data files of the State Geologist's office, the State Energy Office and the Georgia Tech library. Data collected included location of coal deposits, location of all oil and gas wells drilled in Georgia, location of all hydroelectric plants in the state, location of all coal and nuclear electric generation facilities, and location of all geothermal and mineral springs in Georgia. These data were collected by METRICS and supplied to EES for inclusion in the Georgia natural resources data base.

The second subtask was accomplished via a review of current and past Landsat research projects and a review of those areas where land use and energy might be related. Specific projects were identified where computer processed Landsat data would serve as a useful tool for studying the relationships between energy and land use. The critical feature of all these projects so identified is that computer processed Landsat data would be taking its place along with census data, socioeconomic data, or other conventional data sources as an operational tool in various planning or evaluation studies.

The results of this effort were documented in a working paper. The specific areas where additional investigations are recommended include:

* The relationships between energy consumption and urban development patterns;
* The energy efficiencies of planned <u>versus</u> unplanned communities;
* The effects of urban development patterns and energy utilization on urban climate; and
* The assessment of the environmental impacts of energy plantations.

With the renewed emphasis in this country on energy conservation, these proposed research projects should be given additional consideration. The results could have long-range implications for energy consumption in the U.S.

The third task - investigating the use of Landsat data for evaluating the biomass potential of underutilized land - is discussed in detail in the following paragraphs.

## Biomass as an Energy Source

Biomass as a fuel is not a radical idea - even in industrialized nations.[12] For example, Sweden gets 8% of its energy from wood, and Finland gets 15% of its energy from wood. In the U.S. wood and wood-based materials are used by industry to generate more power than is produced by nuclear power stations. This results from the large use of wood residues by the wood products industry to meet a portion of its power needs. For example, the pulp and paper industry utilizes 2.3 quads of energy annually (1 quad = $1.1 \times 10^{18}$ joules = $10^{15}$ BTU). Wood residues furnish about 37%, or almost 1 quad, of this energy.

Biomass as a fuel can originate from several different sources. The major sources are:

- Nonused residues from plant and animal production activities,
- Plant crops grown specifically for fuel, and
- Residues of plant and animal materials that have already provided for their primary use.

Nonused residues are the byproducts of the production of plants and animals for food and fiber. These include such resources as timber harvest residues in the form of limbs, tops, stumps, etc., left in the woods following logging; stalks, husks, straw and other similar residues of agricultural feed crops; and manure from livestock feed lots. Plant crops grown specifically for fuel include trees (e.g., pine and sycamore) or food crops (e.g., corn or wheat). Residues of plant and animal materials that have performed their primary function are primarily urban and municipal solid wastes which contain a large fraction of biomass.

The third item - urban and municipal solid wastes - is of no concern here. The first two sources of biomass are examined in more detail below.

The potential for utilizing nonused residues as fuel is great. Total nonused residues from forestry production are estimated to be about 280 million cubic meters (10 billion cubic feet) annually. This could be converted to approximately 2 quads of energy. Over 300 million tonnes (dry weight) of plant crop residues are also left in fields and could be made available for fuel. It is estimated that U.S. food production could double in the next 20 years and that this would result in a doubling of agricultural residues that could be used for fuel. The USDA Outlook Study[13] indicates that current forest production represents only half of the biological potential of U.S. forest land at current low levels of silviculture. Thus the nonused residues from forestry production could also double.

Besides the renewable nature of biomass, environmental considerations also favor it as an energy source. Wood and agricultural residues have some unique advantages over fossil fuels and nuclear power sources in terms of environmental impact. Among these are:

- Sulfur content is low or nonexistent,
- Harvesting of biomass does not cause the land disorganization associated with extraction of coal or oil shale, and
- Residues from wood fuel combustion are easily disposed of; wood ash can be used as fertilizer.

Fuel Potential of Biomass in the Southeast

The Ohio Agricultural Research and Development Center has investigated the possibility of growing crops as an energy source.[14] Nine U.S. crops were found to be suitable for biomass production: alfalfa, corn, kenaf, napier grass, pine trees, potatoes, sycamore trees, sugar beets, and wheat. Three of these, however, were rejected because of their lesser biomass production potential. These crops are potatoes, sugar beets, and wheat.

Several factors tend to limit the areas where biomass fuel crops may be grown. These are:

- Crop management,
- Nutrients,
- Soil drainage,
- Water
- Temperature, and
- Solar radiation.

Most of the Southeastern states (and Georgia in particular) meet the requirements for solar radiation, temperature (minimum of 125-150 frost-free days in growing season), and water (50-75cm or 20-30" per growing season). The other limiting factors, then, are the only ones of concern in the Southeast.

According to data derived by the Ohio Agricultural R&D Center, the best crops for biomass production in the Southeast are kenaf, sycamore trees, and pine trees. Corn is an additional possibility but it is not rated as high as the others. The cycle time, crop yields, costs, energy requirements for production, and the energy ratio is given in Table 8. Based on costs of production, corn and kenaf would be the lowest cost sources of biomass and would be adaptable to large areas of the U.S. (including the Southeast). Based on energy efficiency (ratio of energy input to energy potential produced), pine and sycamore are the most productive crops. These trees are well suited to most of the Southeast.

Kemp et al.[15] indicate also that the cost of fuel produced by conifers is higher than that from annuals. Nevertheless the authors conclude:

Table 8. Characteristics of Potential Energy Crops[13]

| CROP | CYCLE TIME (YRS) | CROP[1] YIELD $t/hm^2/Yr$ | COST* PER TONNE (ton) | ENERGY[2] INPUTS MJ/t | ENERGY*,3 RATIO (J/J) |
|---|---|---|---|---|---|
| Alfalfa | 3 | 12.1 (5.4) | $41.09 ($37.28) | 1100.2 (.94) | 14.1 |
| Corn+ | 1 | 19.3 (8.6) | $29.06 ($26.36) | 1287.4 (1.1) | 12.0 |
| Kenaf+ | 1 | 19.5 (8.7) | $27.75 ($25.17) | 1168.6 (1.0) | 13.3 |
| Napier Gross** | 3 | 50.5 (22.5) | $18.22 ($16.53) | 1176.8 (1.0) | 13.1 |
| Slash Pine+ | 20 | 14.5 (6.5) | $32.06 ($29.08) | 612.7 (.52) | 25.3 |
| Sycamore+ | 10 | 16.2 (7.2) | $31.00 ($28.12) | 888.7 (.76) | 17.4 |

* Not including transportation and efficiency of biomass conversion to a suitable energy form.

\+ Generally suitable for Southeast.

** Suitable only for portions of South Florida and Puerto Rico.

1 $t/hm^2$ = tonnes per square hectometer; ( ) = tons/acre/year

2 MJ/t = Mega Joule/tonne; ( ) = ($10^6$ Btu/Ton)

3 J/J = Joules output/Joules input.

"The advantages offered by perennials over annuals are crucial to the feasibility of energy plantations. Perennials can be harvested throughout the year in response to the demand for fuel, whereas annuals must be planted and harvested on nature's schedule. This means that in those localities where only one annual crop per year is possible, which is the case for most of the United States, a harvested product inventory equivalent to at least a year's supply of fuel will have to be established at harvest time. Storing and preserving such an inventory would be a substantial and costly proposition. Perennials on the other hand preserve themselves until harvested."

Therefore, the choice of crops to plant (for example, trees or corn) probably will be based on the particular economic and institutional circumstances at the time and place where such energy farms are being considered.

## Preliminary Use of Landsat Data for Evaluating Biomass Potential

Based on the above considerations, there are two possibilities for using Landsat data to inventory underutilized land as possible sites for biomass production. These possibilities are:

- Evaluating soil drainage conditions, and
- Identifying natural forest areas where silviculture could be practiced to increase biomass yields.

As previously discussed, three of the limiting factors identified by the Ohio Agricultural R&D Center are not generally applicable to the Southeast. Of the other three, only soil drainage is amenable to investigation by remote sensing methods. Hence, Landsat data might be used to identify well drained areas (nonforested) where commercial crops are not presently being grown. Since well drained soils are much more productive than poorly drained soils, these are potential sites for planting one or more of the suitable energy crops. Of course, the production of energy crops would still compete in the market place (on an economic basis) for crop management talent and plant nutrients (e.g., fertilizer).

Landsat data has several potential roles in identifying well drained areas suitable for growing energy crops. First, Landsat data can be utilized for evaluating overall drainage patterns of an area. Landsat

data overlayed with digital topographic data can provide still more information about drainage conditions. Finally, for those areas identified as potential sites, a vegetation or land cover analysis can be performed to determine the types of vegetation present and whether or not the land is in commercial production. This latter information is important for two reasons: first, vegetation type is often an indication of soil moisture conditions; and second, energy crops, at present, cannot compete economically with food and fiber crops. Therefore, the most likely areas for growing energy crops are those not presently in commercial production.

The above data could be supplemented by thermal and/or microwave remote sensing to get a more complete picture of soil moisture conditions. For example, data recorded by Skylab's 13.9 Ghz scatterometer used over a test site in Texas was used to correlate the measured scattering coefficient with soil moisture content.[16] The correlation coefficient calculated on the basis of linear regression analysis was 0.67. Other researchers, including Werner and Schmen,[17] have utilized thermal sensors in assessing soil moisture conditions. Since Landsat C will have a thermal channel, this additional data source will be available for assessing soil drainage conditions.

Landsat data should also be useful for identifying forest areas where silviculture is not practiced, e.g., natural forest areas. While no references to research on this specific topic could be found, enough is known about the characteristics of Landsat data to assure at least partial success. For example, it is known that areas of hardwoods and areas of mixed hardwoods and conifers can be identified using four band multispectral aerial photography and computer processed Landsat data.[18,19] Since silviculture is not being practiced in these areas, they are potential sites for silviculture. It is not known with certainty if areas of silviculture can be differentiated from pure stands of natural pines. However, there is evidence to indicate that this is possible, at least in some areas.

## Summary and Conclusions

In the Southeastern U.S. there are at least two tree types (pine and sycamore) and two crops (kenaf and corn) that could be grown as energy sources. While current energy costs and the economics of food and fiber

production do not presently favor the growing of energy crops, circumstances may change in the future to favor renewable energy resources over nonrenewable energy sources.

On the basis of this preliminary assessment, it appears that Landsat data (and other forms of remote sensing data) could play a significant role in inventorying potential sites for the production of energy crops. These sites would include well drained areas on which commercial crops are not grown and forest areas where silviculture is not practiced.

# VIII

# RESULTS AND CONCLUSIONS

Results of this project indicate that its primary objective - the transfer of remote sensing technology for the digital processing of Landsat data to state and local user agencies - was attained. Evidence of this is found in the well-attended technology transfer sessions, the extensive cooperation by state and local agencies in the early phases of the project (Douglas County and Hall County test sites), and the financial commitment by a number of federal, state and local agencies to mapping the State of Georgia using digital Landsat data.

Several secondary objectives of the project were also accomplished. Computer processing of Landsat data using the USGS/NASA land use classification system was shown to result in accuracies ranging from 67 to 79 percent. Landsat data were shown to have utility in providing land use information for the Georgia Department of Transportation Planning Land Use Model. The cost-effectiveness of computer processed Landsat data for use in the Georgia DOT model was demonstrated. A study of geobotanical indicators of the Brevard Fault Zone in Douglas County and Hall County demonstrated the use of vegetation mapping from Landsat data to study geological structure. A preliminary investigation concluded that Landsat data were useful in evaluating potential sites for growing biomass as an energy source. Finally, NASA-developed hardware concepts and computer software were transferred to state agencies in Georgia.

The technology transfer methodology employed in this project consists of a series of demonstration projects coupled with formal technology transfer sessions. The combination of these two mechanisms appears to have been highly successful. In Georgia, where the majority of the technology transfer efforts have been concentrated, seven state and local agencies have combined with four federal agencies to fund a Landsat computer mapping project for the entire State of Georgia. Several other state and local agencies are interested in the mapping project but as yet have supplied no funds.

## References


1. Spann, G. W., and Faust, N. L., Digital Analysis of Landsat Data, EES Final Report, Project A1557, 1974.

2. Spann, G. W., and Faust, N. L., "Study of USGS/NASA Land-Use Classification System," Engineering Experiment Station, Interim Technical Report, Georgia Institute of Technology, for NASA/MSFC, December, 1974.

3. Hailperins, M. P., Maggied, H. S. and Floyd, C. S., "The Georgia Transportation Planning Land Use Model", Proceedings of the 57th Annual Conference, American Institute of Planners, October, 1975.

4. Vegas, P. L., "A Detailed Procedure for the Use of Small Scale Photography in Land Use Classification," Earth Resources Laboratory, National Space Technology Laboratories.

5. Faust, N. L. and Spann, G. W., "Landsat Data for State Planning," Engineering Experiment Station, Annual Report, Georgia Institute of Technology, for NASA/MSFC, December 1975.

6. The Economic Value of Remote Sensing of Earth Resources from Space, An ERTS Overview and the Value of Continuity of Service, ECON, INC., Volume VI, Part II, page 3-17, NASW-2558, December, 1974.

7. Earth Resources Survey Benefit-Cost Study, Earth Satellite Corporation and Booze-Allen Applied Research, Contract Number 135-19; USGS, Appendix 5, page iii, November, 1974.

8. Personal Communication

9. Personal Communication

10. Personal Communication

11. Spann, G. W., "Study of USGS/NASA Land Use Classification System, Engineering Experiment Station, Final Technical Report, March, 1975.

12. Bethel, James S., Renewable Resources for Industrial Materials, National Research Council, Washington, D.C., September 1976, PB 257-357.

13. U.S. Department of Agriculture, "The Outlook for Timber in the U.S.", Forest Resource Report 20, Washington, D.C., 1974, USGPO.

14. Roller, W. L., et al., Grown Organic Matter as a Fuel Raw Material, Ohio Agricultural Research and Development Center, Wooster, Ohio, October 1975, N76-10569.

15. Kemp, C. C., et al., "The Energy Plantation", in Proceedings of the 8th Cellulose Conference, No. 1: Wood Chemicals - A Future Challenge, p. 11-19 edited by T. E. Tinell, New York, John Wiley.

16. Eagleman, J., and F. T. Ulaby, "Radiometer-Scatterometer Soil Moisture Detection", Proceedings of the American Astronomical Society, August 1974, Los Angeles, California.

17. Werner, H. E., and F. A. Schner, "Application of Remote Sensing Techniques to Monitoring Soil Moisture", Report No. 71-3, South Dakota State University, Remote Sensing Institute, June 1971.

18. Downs, Sanford W., Jr., "The Use of Four Band Multispectral Photography to Identify Forest Cover Types", to be published in Proceedings of the Sixth Annual Remote Sensing of Earth Resources Conference, March 1977, University of Tennessee Space Institute, Tullahoma, Tennessee, F. Sharohki, Editor; and Personal Communication.

19. Kalensky, Z., and L. R. Scherls, "Accuracy of Forest Mapping from Landsat Computer Compatible Tapes", in Proceedings of the Tenth International Symposium on Remote Sensing of Environment, October 1975, Environmental Research Institute of Michigan, Ann Arbor, Michigan.

## APPENDIX A

## THE ERDAS SYSTEM

The Georgia Tech Earth Resources Data Analysis System (ERDAS) was designed and constructed by EES to allow true interactive digital processing of all types of remote sensing data (Figure A-1). ERDAS consists of a set of 4 modules: 1) minicomputer subsystem, 2) input medium, 3) hardcopy output medium, and 4) display subsystem.

The minicomputer subsystem consists of a NOVA-2/10 minicomputer with 64000 bytes of core memory and a dual Diablo disk system with 5.0 megabytes of storage for programs or data. The unput medium for the ERDAS system is a set of two nine track dual density (phase encoded/ NRSI selectable) magnetic tape drives and controller -- both drives with a capacity for 10 (ten) 1/2 inch reels of tape.

The hardcopy output medium is a twenty inch electrostatic dot matrix printer/plotter. Scaled maps of Earth Resources data can be made using this medium. A CROMALIN$^{(R)}$ photographic process may then be used to generate a color coded output hardcopy product. Color products may also be obtained through a service offered by a commercial producer of film writers.

The display subsystem consists of a high quality video monitor that is interfaced to the minicomputer for complete user interaction in the choice of training samples for earth resources classification.

Elements of the subsystem are:

1. Color monitor
2. Trackball cursor
3. Self contained refresh memory
    a. one image 512 x 512 elements by 8 bits or
    b. three image 256 x 256 elements by 8 bits

ERDAS is a completely software oriented system. Training statistics can be calculated instantaneously for cursor located fields. A histogram may then be displayed to check homogeniety of training fields. Classification may be performed on stored data sets or data sets read in from the

system's magnetic tape drives. This system is inherently interactive, and ratioing of MSS bands, level slicing, classification, and change detection software will provide display data to be fed to the color monitor.

The EES ERDAS System may be used in either of two general modes. In Mode 1 an image may be displayed on the display screen with a resolution of 512 by 512 elements with data values ranging from 0 (black) to 255 (white). These data values may be color coded via a psuedo color memory to produce a false color display of the image. The user may select sixty-four display colors from a possible variety of 4096 colors (4 bits for each color gun). The colors are arranged in the pseudo color memory such that for example, data values 0-3 are assigned in the pseudo values, 4-7 are assigned the next, etc. A pseudo color scale that is often used varies from dark blue to green, yellow, orange, and red with different shades and combinations of these colors filling out the chart. This method is often used is displaying an image in as nearly a natural color state as possible (Figure A-2).

In addition to the pseudo color capability of the ERDAS System, it also has the capability of passing the original data values through a function memory before the data are displayed. As with the pseudo color memory, this function may be selected by the user. For example, if a linear function memory with a slope of one is to be used, a value "0" would be coded as a zero, a 10 as a 10, and so on. If, however, a linear function is selected with a slope of 2, a value "0" would be coded as a "0" but a 10 would be coded as a 20, and so on. After the value of 127 is coded to a 254, all subsequent values would be coded as 255. The function memory may be envisioned by a two dimensional grid with the bottom axis as the original data value and the vertical axis as the coded data value. The two examples given above are shown in Figure A-3. A logrithmic example is also given in Figure A-4. This capability allows the dynamic density stretching or compression of any image by linear or nonlinear functions. In all cases the data in the image memory remains the same as the original image. The function only operates on the portion of the image that is displayed on the television screen.

The second mode of the ERDAS System has a resolution of only 256 by 256 elements on the television screen but three Landsat or other images may be displayed at the same time. As before, each image contains data values between 0 and 255, but in this case each image may be assigned specifically to one color gun of the television (Figure A-5). For Landsat data, normally three of the four channels of Landsat data are assigned to individual color guns. If channel one and channel two (visable bands) of Landsat data are applied to the blue and green guns, and channel 4 (near infrared) is applied to the red gun, a simulated near infrared image is displayed on the screen. This type of picture incorporates three channels of Landsat data at one time and results in a very similar color scheme to that of color infrared aerial photography. This technique has been most effective in the location of training fields for Landsat classification (Figure A-6) and as an aid in interpretation of the raw Landsat image.

All of the function memory and pseudo color memory operations discussed above may be performed in this mode also for each of the three images. For example, three different functions may be applied to the three images and the result shown as an enhanced color infrared display.

The remote sensing data at EES are processed by one or more picture processing computer programs. Basic analysis modules available are:

1. Supervised Classification (Maximum Likelihood)
2. Linear Supervised Classification
3. Sequential Unsupervised Classification (Clustering)
4. Non-Sequential Clustering (ISODATA)
5. Histogram Generation
6. Level Slicing
7. Registration and Rectification
8. Factor Analysis
9. Grey Scale Display
10. FFT (Fast Fourier Transform)
11. Change Detection
12. Polygon Training Field
13. Polygon Classification
14. Edge Enhancement
15. Ratioing

Figure A-1. ERDAS System

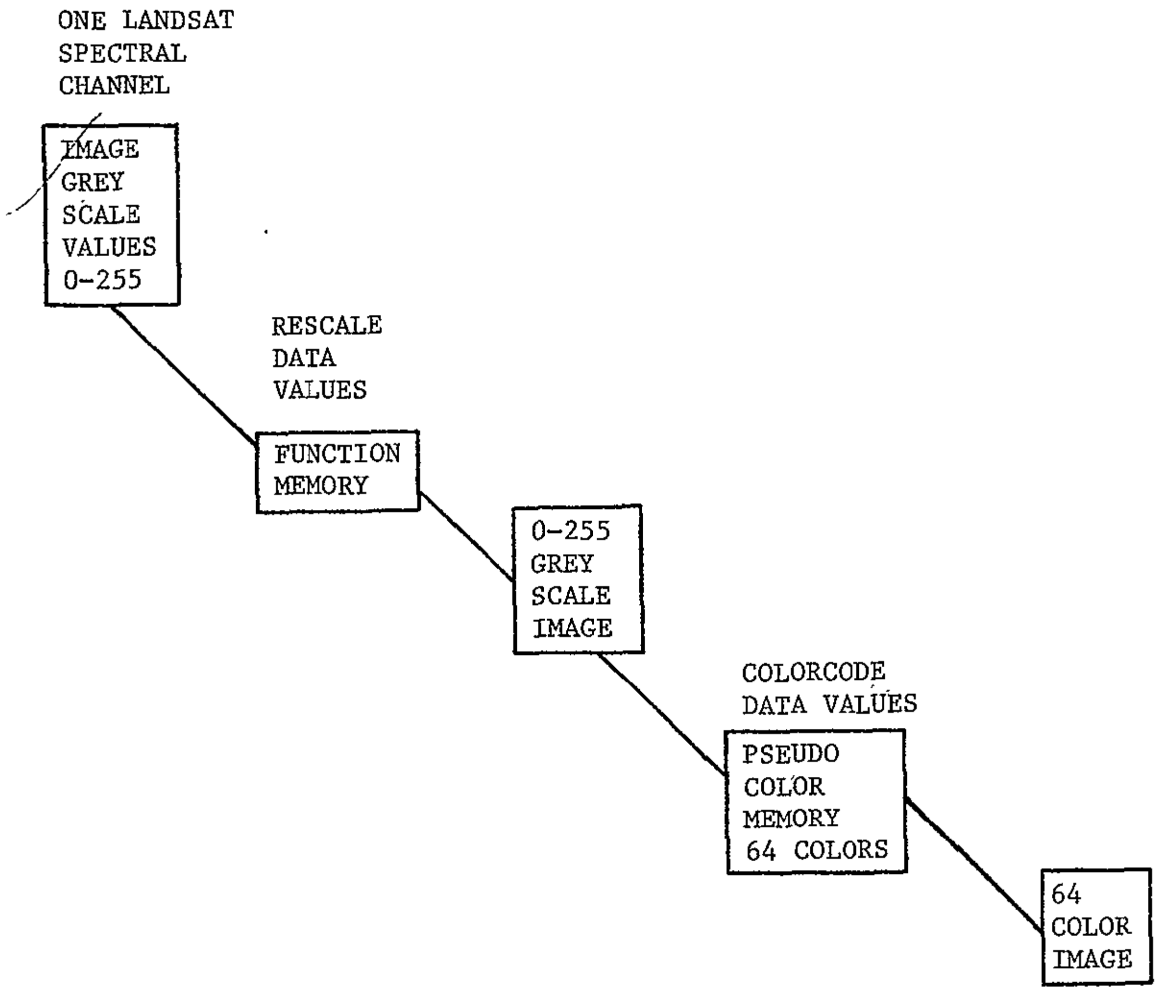


Figure A-2. Color Video Display - Mode 1

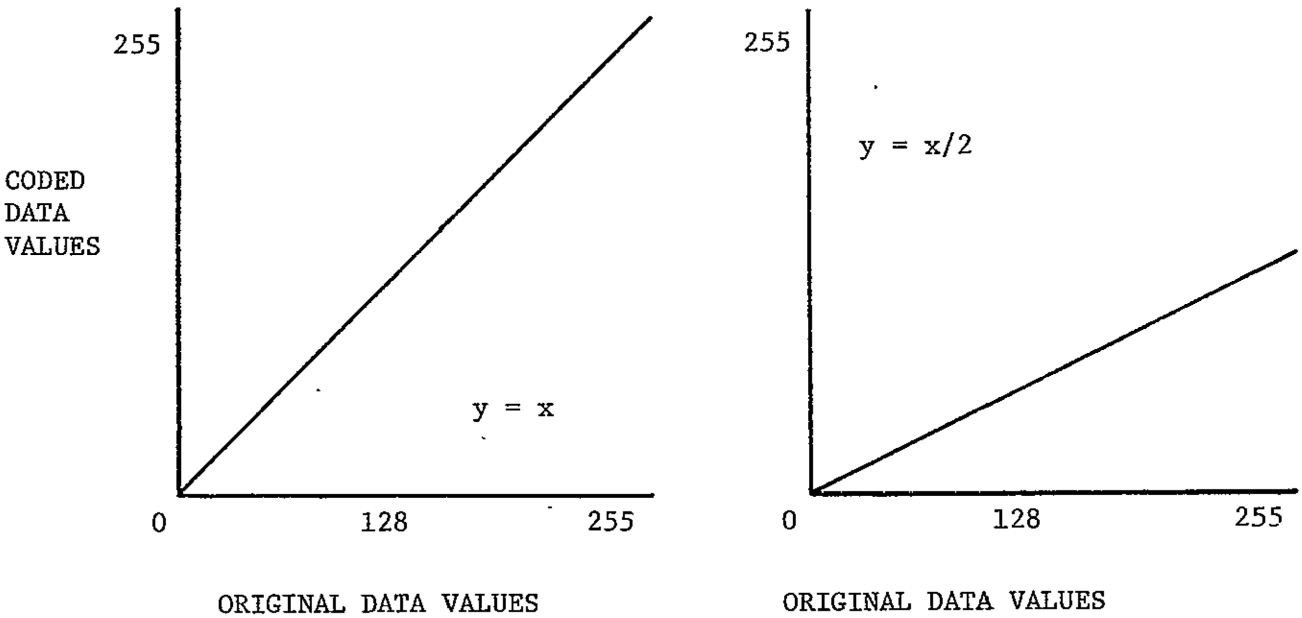


Figure A-3. Linear Function Memory Example

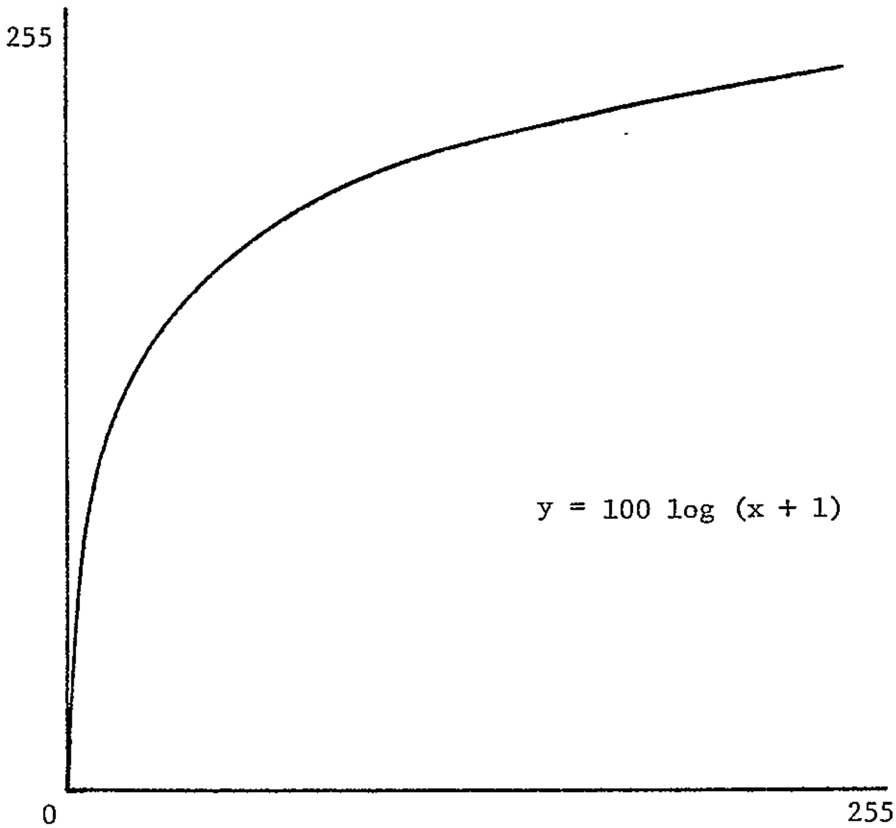


Figure A-4. Logrithmic Function Memory

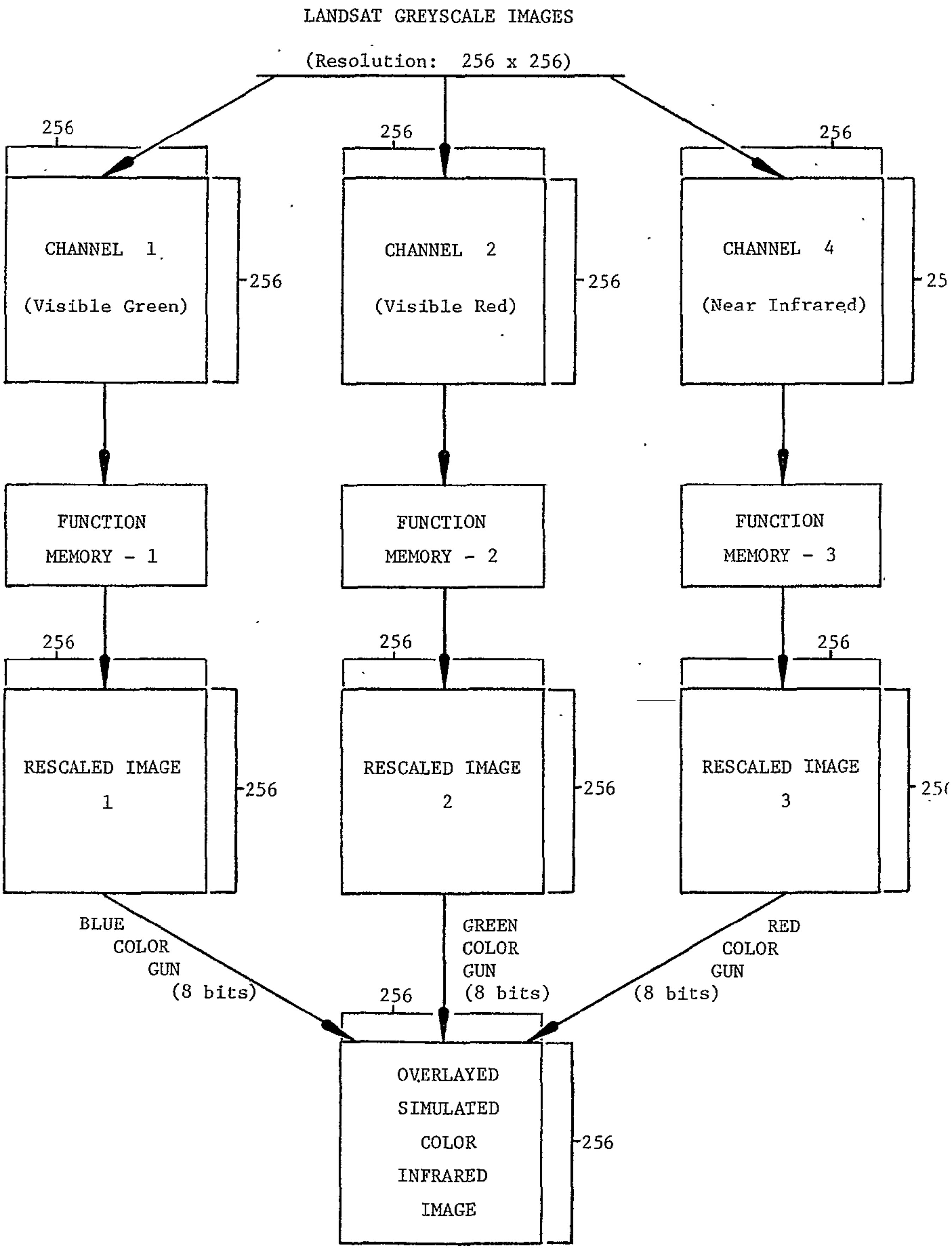


Figure A-5. Block diagram of Mode 2 of the Color Video Display